PHYTOPATHOLOGY

VOLUME 27 NUMBER 2

FEBRUARY, 1937

ABSTRACTS OF PAPERS ACCEPTED FOR PRESENTATION AT THE TWENTY-EIGHTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, ATLANTIC CITY, NEW JERSEY, DECEMBER 28 TO 31, 1936[1]

PAGE

AHRENS. Development and Experiences in the Use of Apparatus for Pouring and Washing Agar Plates 121

BANFIELD. Distribution of Spores of Wilt-inducing Fungi Throughout the Vascular System of the Elm by the Sap Stream 121

BEALE. Possible Relationship of Stanley's Crystalline Tobacco-mosaic-virus Material to Intracellular Inclusions Present in Virus-infected Cells 122

BEATTIE. The Dutch Elm Disease in Europe 122

BROWN. A Comparison of Linted and Acid-delinted Cotton Seed 122

BURRELL. Symptoms and Terminology in Some Physiogenic Apple Diseases 123

BURRELL and MILLER. Boric Acid Treatment of a Physiogenic Apple Disease 123

CARTER. Cultural Characters of Thyrostroma compactum from Chinese Elm 123

CHESTER. The Limitations of Plant-virus Serology 124

CLAYTON. Spraying as a Method of Control for Mildew (Peronospora tabacina) and Wildfire (Bacterium tabacum) in Tobacco Plant Beds 124

COOK. Germination of Conidia of Peronospora effusa from Spinach 124

COOK. Sclerotinia sclerotiorum on Pyrethrum 124

COOK. Cucumber Mosaic in Puerto Rico 125

COOK. The Witches'-Broom of Tabebuia pallida Caused by a Virus 125

COONS, KOTILA and STEWART. Savoy, a Virus Disease of Beet Transmitted by Piesma cinerea 125

COLE. Bunch Disease of Pecans 125

CRANDALL, HARTLEY and DAVIDSON. Wetwood 126

D'AETH. The Interaction of Two Apple-rotting Fungi 126

DAINES and MARTIN. Reduction of Bordeaux Mixture Injury by the Use of Amendments 126

DAVEY. Nitrogen Supply of Sugar Beets in Sand Culture in Relation to Extent of Injury by Southern Sclerotium Rot 126

DAVIDSON, CAMPBELL and BLAISDELL. Cultural Identification as a Necessary Supplement to Tree Decay Studies 127

DAVIS. The Cercospora Leaf Spot of Rose Caused by Mycosphaerella rosicola 127

DAVIS, LATHAM and YOUNG. Some Disease Developments in Forest Nurseries 127

DUNLAP. Seed Treatment in Relation to Sand Culture of Seedlings 128

[1] Since the Society does not require publication in PHYTOPATHOLOGY, or elsewhere, of papers presented at meetings, there is no certainty that the material covered by any particular abstract will appear later as a published article. These are not abstracts of published papers.

ERWIN. Corticium Disease of Turf 128
FOSTER. Environmental Conditions Influencing the Development of Tomato Pockets or Puffs 128
FOSTER. Environmental Factors Influencing the Development of Blossom-end Rot of Tomatoes 128
GARDNER, TOMPKINS, and THOMAS. Factors Affecting the Prevalence of the Spotted Wilt Virus 129
GLOYER. Evaluation of the Geneva Experiment on Scab Control 129
GRAVES. Breeding Disease-resistant Chestnut Trees 129
HAENSELER. Control of Club Root of Crucifers 130
HARRAR. Cercospora Leaf Spot of Calendula 130
HARTZELL. Movement of Intracellular Bodies Associated with Peach Yellows 130
HENDERSON. Histological Studies of Infection and Sporulation of Peronospora tabacina in Tobacco Seedlings 131
HILDEBRAND and HSIONG. Inheritance of Plant Characters and Resistance to Fire Blight in Pear 131
HOLMES. Hereditary Factors Affecting Tobacco-mosaic Disease in Solanaceous Plants 131
HORSFALL, MAGIE, and CUNNINGHAM. Effect of Copper Sprays on Ripening of Tomatoes 132
IMLE and SAMSON. Studies on a Ring Spot Type of Virus of Tomato 132
IVANOFF and KEITT. Aerial Bacterial Strands in Fire Blight 132
KEITT and CARPENTER. Experimental Spraying for Combined Control of Apple Scab and Fire Blight 133
KEITT and PALMITER. Eradicant Fungicides in Relation to Apple-Scab Control 133
KIRBY, BURKE and BAUER. The Use of Movies in Teaching Symptoms and Control Measures of Cabbage Diseases 133
LEHMAN. Contaminated Soil in Relation to the Epiphytology of Tobacco Mosaic 133
LEVINE. Crown Gall on Nicotiana glauca and Nicotiana langsdorffi and the Spontaneous 'Tumors' of Their Hybrid 134
LOCKE, RIKER and DUGGAR. A Growth Hormone in the Development of Crown Gall 134
LOJKIN. Inactivation of Tobacco-mosaic Virus by Ascorbic Acid 134
LORING and STANLEY. Comparative Properties of Virus Proteins from a Single-lesion Strain and from Ordinary Tobacco-mosaic Virus 134
MCCULLOCH. An Iris Leaf Disease Caused by Bacterium tardicrescens, n. sp. 135
MCNEW. Isolation of Pathogenic Variants from Pure Cultures of Bacterium stewarti 135
MCWHORTER. Didymellina poecilospora, n. sp., a Semiparasitic Heterosporium on Bulbous Iris 135
MONTEITH, JR. Control of Rhizoctonia with Aniline Dyes 136
NAGY, PETERSON and RIKER. Comparison of Enzymes in Crown-Gall and Noninoculated Plant Tissue 136
NEAL. A Disorder of Cotton Plants Recently Observed in Louisiana 136
NELSON. Verticillium Wilt of Peppermint 137
NELSON. Basal Dry Rot of Gladiolus Corms 137
OWENS. Blue Stain of Cotton is Due to a Fungus 137
ORTON and HILL. An Undescribed Potato Disease in West Virginia 137
PALMITER and KEITT. Studies of Copper-Lime-Arsenite Dusts for Control of Wheat Bunt 138
PIRONE. Marigold Wilt 138
PRICE. Classification of Lily-mosaic Virus 138
RYKER. Root Rot of Rice 139

SCHNEIDERHAN. Methods and Results of Studying Some of the Factors Involved in Spray Injury of the Apple 139
SLEETH and ROTH. Basal Decay in Oak Stands of Sprout Origin 139
SMITH. Studies on the Host Range of Bacterium solanacearum 140
SMUCKER. Relation of Injuries to Infection of American Elm by Ceratostomella ulmi 140
SPENCER. Influence of Nutrition on Systemic Development of a Yellow Strain of Tobacco Mosaic 140
TAPKE. Seasonal Cycle of Ustilago hordei 141
TAUBENHAUS. Laboratory Studies on the Fungicidal Properties of Sulphur 141
TAYLOR. Separation of Actinomyces Isolates Obtained from Scabbed Potatoes and from Soil 141
TIDD. Inheritance of Resistance of Barley to an Undescribed Physiologic Form of Erysiphe graminis hordei 141
TIDD. Reaction of Barley to Two Undescribed Physiologic Races of Barley Mildew, Erysiphe graminis hordei 142
WALKER. The Fungicidal Value of Mustard Oils 142
WALKER and LARSON. Increasing Importance of Cabbage Mosaic 142
WALTER and MAY. Pathogenicity of a Brown Cultural Variant of Ceratostomella ulmi 142
WATKINS. Penetration and Invasion of Phymatotrichum omnivorum in Cotton Roots Grown Under Pure-culture Conditions 143
WEISS. Antiseptic and Disinfectant Treatments of Flowering Bulbs 143
WEISS and POST. Noninfectious Chlorosis of Perennial Phlox and Its Relations to Phlox Blight 143
YOUNG, DAVIS and LATHAM. Control of Damping Off of Conifers 144
ZAUMEYER. Pea Streak and Its Relationship to Strains of Alfalfa Mosaic 144

Development and Experiences in the Use of Apparatus for Pouring and Washing Agar Plates. W. E. AHRENS.

A machine designed to pour agar plates automatically and deliver them hardened, ready for use in a few minutes, has been developed. Sterile plates are inserted in a hopper from which they pass on an endless belt beneath a cylinder that delivers a measured quantity of medium to the plate. Lids are removed and replaced by a synchronized vacuum system. The poured plates then pass to a cooling tank from which they emerge hardened, ready for use in 5 minutes at the rate of 14 plates a minute.

Another machine of the endless-belt type has been devised to clean and wash poured plates. Lids and bottoms are separated by an operator and fed into the machine in separate slides. The medium is removed by a jet of steam striking the inverted plate. Wax pencil markings are erased by a sheepskin belt saturated with xylene. Plates now pass through a tank of boiling soapsuds and then they are rinsed, top and bottom, by streams of fresh water sprayed on them from a centrifugal pump. After rinsing, the plates emerge at the rate of 14 a minute and are reassembled by a second operator.

Distribution of Spores of Wilt-inducing Fungi Throughout the Vascular System of the Elm by the Sap Stream. W. M. BANFIELD.

Spore suspensions of fungi inducing elm wilts, including *Ceratostomella ulmi*, were injected into the bases or tops of 4- to 8-inch elms from early spring to late autumn. Three hours to 3 weeks after injection the limits of distribution of the spores were determined by identification of the fungi in cultures made from centrifuged sap displaced from various levels in the tree or from the subsequently discolored wood. Injection of spores was achieved by cementing a funnel-shape pan around the stem, filling the pan with spore

suspension, severing in contact with and under the suspension all actively conducting vessels. Sap displacements were made by cementing metal collars around the upper ends of stem sectors, filling the collars with sterile water and collecting the liquid that dripped from the stem bases.

The maximum distribution of the fungi in trees after 3 days in April was 2 inches above and 2 feet below the points of injection. Spores were recovered 30 feet above points of injection after 3 hours in June and 24 feet below points of injection after 2 days in October. *C. ulmi* spores were removed from the sap stream of naturally diseased trees in May, July and September.

Possible Relationship of Stanley's Crystalline Tobacco-Mosaic-Virus Material to Intracellular Inclusions Present in Virus-infected Cells. HELEN PURDY BEALE.

Cytoplasmic inclusions, characteristically present in cells affected with certain strains of tobacco-mosaic virus, are the vacuolate, plasma-like, "x-bodies," and crystalline material, often striated, that occurs in plates, frequently hexagonal, in side-view oblong.

Strips of epidermis from the midribs of leaves, affected with Johnson's tobacco virus 1 or 6, were mounted in water and observed under high magnification. Acid, approximately pH 1.3, was run under the cover slip, and, as the acid penetrated the cells, the oblong crystalline masses developed cross striations, finally breaking up into needles that floated out free in the cells. The crystalline plates formed needles with their long axes at right angles to the basal plane of the plate. Excess acid dissolved the needles, leaving the x-bodies and host nucleus intact.

Using 3 different acids, intracellular precipitation of needle-shape crystals was obtained with 6 different hosts. Needle-shape crystals were not formed in healthy tobacco cells nor in those affected with the viruses of tobacco ring spot or potato x.

In gross appearance, the intracellular-needle crystals were indistinguishable from those formed upon acidification of virus extract, purified according to Stanley's method.

The Dutch Elm Disease in Europe. R. KENT BEATTIE.

The elm is widely distributed in Great Britain. Five species and 2 varieties are recognized. They hybridize freely. The elm disease was first found in 1927. It was already widely distributed and eradication efforts were soon abandoned. It is now within 30 miles of the Scottish border. No Cephalosporium or Verticillium is known in England. The cause of a dieback present in the North of England and Scotland is as yet unknown.

In The Netherlands, elms formerly bordered most of the roads. The disease was first observed at Tilburg in 1919 and was seen nowhere else. It is now widely scattered. Much creditable research has been performed by the Dutch investigators. For 5 years a systematic clean-up has been under way not to eradicate but to delay spread and permit economical utilization.

The elm disease has been in Belgium certainly for 18 years. No efforts to control it are being made.

In France the disease was first noted at Chalons-sur-Marne in 1919. No effort to control it is being made. It was seen between Calais and Paris, around Versailles, at Vichy in central and Bergerac in southwest France.

Burl elms, such as brought the disease to America were seen widely distributed in France and England. Uniform evenly grown burls are not common.

A Comparison of Linted and Acid-delinted Cotton Seed. J. G. BROWN.

The sulphuric acid cotton-seed delinting treatment is a valuable control measure for angular leaf-spot. In addition, it is much easier to sow delinted seed. It has been found that linted and delinted seed do not respond the same when planted at different depths in

wet, heavy soils, and that to take full advantage of the many superior qualities of delinted seed, proper planting is important. These differences in the behavior of linted and delinted seed have been associated with seed air-carrying capacity; to measure which a simple apparatus has been specially devised.

Symptoms and Terminology in Some Physiogenic Apple Diseases. A. B. BURRELL.

"Cork," as commonly applied to apple symptoms, denotes rather large, definitely delimited masses of dead cells within the fruit; drouth spot, extensive areas of superficial necrosis. (1) Correlation in occurrence, (2) parallel response to cultural treatments, and (3) grafting experiments, indicate that cork, drouth spot, a form of dieback and a form of rosette, as occurring in the Lake Champlain Valley, compose a symptom-complex and are not to be regarded as separate diseases. The same symptom-complex evidently occurs in New Zealand, British Columbia, and elsewhere. A name is needed for the disease as a whole, but its choice should await fuller knowledge of the rôle of boron. (See Burrell and Miller abstract.) The variety of apple largely governs whether it takes on the cork type or the drouth spot type of symptom or a combination. The relation to this disease of a late-summer diffused, interior browning of apple flesh, largely controllable by irrigation, is not quite settled. Drouth spot often is mistaken for frost injury or spray injury. Heat injury, sometimes classed with drouth spot, is distinct. The rosette here discussed, is distinct from the zinc-responsive rosette of western U. S., and, of course, from peach rosette.

Boric Acid Treatment of a Physiogenic Apple Disease. A. B. BURRELL and H. J. MILLER.

The symptom complex of this disease includes drouth spot, cork, rosette, and dieback. (See Burrell abstract.) Directly after petal fall, in crowns of 12 young McIntosh and Fameuse trees, a single hole, usually 7/16″ diameter, was bored 2″ diagonally downward, 0.75 to 2.0 grams U. S. P. H_3BO_3 crystals introduced, and hole sealed. When treated, these trees had 1335 rosette twigs of which 92.4 per cent resumed normal growth within 6 weeks. In 7 trees receiving $ZnSO_4$ flakes only 2.0 per cent of 866 rosette twigs recovered. In 6 nontreated checks, with 769 rosette twigs, only 1.4 per cent recovered. On August 10, incipient dieback showed on 1.1 twigs per H_3BO_3 tree, 60.4 twigs per $ZnSO_4$ tree, and 65.5 twigs per check. On August 10 an estimated 2.2 per cent of all twigs showed abnormal second growth on H_3BO_3 trees, 22.3 per cent on $ZnSO_4$ trees, and 20.2 per cent on check trees. Dry H_3BO_3 caused appreciable injury around the hole, but no foliage injury. $ZnSO_4$ caused both types of injury. H_3BO_3 introduction in mature trees gave promising, but inconclusive, results as to fruit symptoms, chiefly because of inadequate yields. Injection of 5 per cent H_3BO_3 solution was highly injurious; 1 per cent usually was not. Soil application of H_3BO_3 crystals for 4 years was noninjurious, but disease symptoms were insufficient to permit conclusions.

Cultural Characters of Thyrostroma compactum, from Chinese Elm. J. C. CARTER.

Although the writer previously reported inability to grow *Thyrostroma compactum,* in culture, subsequent attempts have been more successful. Conidia from a canker developed after November 1, 1935, were collected and planted on potato-dextrose agar May 8, 1936. On May 9 they had germinated, but hyphal growth proceeded very slowly, the linear extension being 40–172 μ in 19 hours and 46–452 μ in 65 hours. Conidia planted May 30 on 5 types of agar: potato-dextrose, corn-meal, malt-extract, malt-extract with *Ulmus pumila* twig decoction, and 3 per cent plain agar with twig decoction, germinated on all. Growth was most rapid on corn-meal and plain twig-decoction agar and slowest on potato-dextrose. Maximum colony diameter, about 3 mm., was attained in 12 days. Conidia remained viable 22 days in the ice box (about 50° F.) but were dead at the end of 3 months. Ger-

minating conidia transplanted to sterilized *U. pumila* twigs or to agar slants did not produce visible growth. The two end cells germinated most frequently, but, not uncommonly, muriform cells germinated at the same time. Germ tubes from basal cells usually branched during the first 24 hours, those from tip cells usually after 48 hours and frequently not until after reaching a length of 200 μ or more. In no case were cell contents observed to pass entirely into germ tubes during germination.

The Limitations of Plant Virus Serology. K. STARR CHESTER.

The blood test for virus identification and classification has been applied to some 60 viruses and virus strains. About half of these give group-specific precipitin tests, the others fail to react serologically. There is a positive correlation between specific seric activity of the virus juices and their ability to retain infectivity when subjected to dilution, heating, and ageing. In general, the viruses which show seric activity are capable of mechanical transmissibility at expressed-juice dilution up to 1: 1000, they resist heating up to about 55° C., and they withstand ageing for 3–4 days or more. This correlation between virus properties and seric reaction suggests that it is the viruses themselves that are responsible for the blood reactions, although the possibility that the reactions are due to by-products of virus activity is not excluded. Failure of virus juices to give specific blood reactions may be due to low concentration, antigenic inactivity, or instability of the virus antigens. In exceptional cases it might be due to the presence of an undetected masked virus strain in the supposedly healthy plant juices used for absorbing the sera. Further progress in virus concentration and stabilization may extend the list of viruses amenable to seric techniques.

Spraying as a Method of Control for Mildew (Peronospora tabacina) and Wildfire (Bacterium tabacum) in Tobacco Plant Beds. E. E. CLAYTON.

The experiments were conducted over the period 1932–1936, inclusive, with the object of developing a spray procedure that would give effective disease control and would not increase transplanting hazards. Many materials and methods of application have been tested. Best results were obtained by a combination of early weekly Bordeaux sprays, followed later by semi-weekly applications of a copper oxide-cottonseed oil spray. This program has been subjected to extensive field tests for 2 years. The results show that field stands from sprayed plants were either equal or superior to those obtained from unsprayed plants; that mildew was reduced to such a degree that it caused no damage, and that almost perfect control of wildfire was obtained. These results were obtained without the aid of soil sterilization, seed treatment, or other sanitation measures.

Germination of Conidia of Peronospora effusa from Spinach. HAROLD T. COOK.

Various factors affecting germination of conidia of *Peronospora effusa* from spinach were studied with spore suspensions on glass slides. The conidia were found to germinate over a temperature range of from slightly above 0° to 30° C. The optimum temperature was between 10° and 15° C. Newly formed conidia did not germinate so well as those a day old. Conidia germinated after 5 days' exposure on detached infected leaves in the laboratory, but remained viable for only 3 days when exposed on dry glass. In some tests the conidia germinated better in dew than in distilled water or lake water. Dew from several plants appeared to be as favorable for germination as that from spinach.

Sclerotinia sclerotiorum on Pyrethrum. HAROLD T. COOK.

Sclerotinia sclerotiorum was the cause of a very destructive disease in an experimental planting of *Chrysanthemum (Pyrethrum) cinerariaefolium* at Norfolk, Virginia, in the spring of 1930. Counts showed that the disease increased from 9 per cent infected plants on April 28 to 12 per cent dead and 60 per cent infected plants on May 28. Symp-

toms of the disease are wilting of leaves followed by collapse of young stems. Frequently only part of the plant is affected at first, and the collapse of the stems causes a bald or nest-like spot in the plant. Later, the entire plant becomes infected and dies. The fungus mycelium is present in the crown of the plant in the early stages of the disease and soon gives rise to sclerotia, both on the surface and within the stems. Apothecia were found arising from sclerotia buried in the ground and from those inside the stems.

Cucumber Mosaic in Puerto Rico. MELVILLE T. COOK.

During the winter of 1935–36 we had a severe outbreak of mosaic, amounting in many cases to as much as 100 per cent infection. This is the first severe outbreak observed in Puerto Rico in 13 years. The writer's studies failed to show the source of the infection. His studies showed the same morphological characters of the host as reported by him for the other virus diseases.

The Witches'-Broom of Tabebuia pallida Caused by a Virus. MELVILLE T. COOK.

This disease has been attributed to a fungus. Tissue inoculations have demonstrated that it is caused by a virus. It has not been transmitted by seeds.

Savoy, a Virus Disease of Beet Transmitted by Piesma cinerea. G. H. COONS, J. E. KOTILA, and DEWEY STEWART.

Affected plants (sugar beet, garden beet) show dwarfed, down-curled, savoyed leaves, most pronounced effects being found on innermost leaves. Primary symptoms are veinlet clearing followed by thickening of veinlets, giving the dorsal leaf surface a netted appearance. Roots of affected plants show, in late stages, phloem necrosis and flesh discoloration, simulating curly-top effects. From initial partial leaf- and root-involvement, the disease becomes general. Affected roots test low in sucrose. The virus has been transmitted by adults of *Piesma cinerea*, viruliferous and non-viruliferous individuals being found. The virus overwinters in affected plants and in the vector. Incubation period in sugar beet is 3 to 4 weeks. Attempts at transfer by means of juice, aphids (*Mysus persicae, Aphis rumicis*) and leaf hoppers (including *Eutettix tenellus*) have been unsuccessful. The disease has general distribution in Michigan, Ohio, Minnesota, Nebraska, South Dakota, Colorado, and Wyoming, incidence ranging from trace to 5 per cent. The disease discribed for Indiana by Arthur and Golden (1892) and "leaf curl" noted in Michigan (1901) may represent early records. "Savoy" differs distinctly from curly top, and from the German *Kräuselkrankheit* of beets transmitted by *Piesma quadrata*. The disease may be expected to remain a relatively minor factor affecting crop production.

Bunch Disease of Pecans. J. R. COLE.

Bunch disease of pecans, which, in the spring of 1932, was definitely determined to be new to that species, was first observed in the Red River Valley of Louisiana, near Shreveport. The disease is thought to have first attacked the wild native pecan, *Hicoria pecan*, and the water hickory, *Hicoria aquatica*, both species being indigenous to the alluvial river-bottom soils and spreading gradually to the susceptible improved varieties of *H. pecan*. The bunch disease is known to be present in Louisiana, Mississippi, Oklahoma, and Texas. Characteristic and distinguishing symptoms of this disease are the brooming of branches and shoots, early foliation of diseased branches in the spring, chlorotic, thin, broad, wavy, and flexible leaves, and, in later stages, dying back of the branches. Bunch has certain symptoms similar to rosette and little-leaf of pecans; two important diseases of peaches, phony peach and yellow peach, and witches'-broom of black locust. The disease was successfully transmitted by grafting diseased Schley scions onto healthy Schley stocks. The Schley and Mahan varieties are very susceptible, while the Stuart is highly resistant to the disease.

Wetwood. BOWEN S. CRANDALL, CARL HARTLEY, and R. W. DAVIDSON.

At the meeting of two years ago there was reported a bacterial vascular disease in the Salicaceae, characterized by a water-soaked condition of the central wood. It now appears that this wetwood is of frequent occurrence, in most cases without perceptible effect on the health of the tree. It has been found commonly in 9 species or distinct forms of Populus, 3 of Salix, and 5 of Ulmus; in single species of Abies, Tsuga, Prunus, Morus, and Prosopis, in young Platanus and in cuttings of Elaeagnus; and rarely in the inner sapwood region of 3 species of Quercus. Fermentation odors are noticeable, particularly in elm; the wetwood where tested by direct application of an indicator has shown pH values higher than live sapwood and much higher than generally shown by true heartwood. Bacteria have been obtained in culture from wetwood in representatives of all the above phanerogamic genera except Prosopis. Pathological phenomena which seem to be associated in some cases are the dying of Lombardy poplar, *Salix caprea*, *Platanus* sp., *Quercus borealis*, and cuttings of Elaeagnus; slime flux in several species, and subsequent decay due to secondary fungus infection. Preliminary inoculations with bacteria from *Platanus* sp. produced wilt in Platanus cuttings.

The Interaction of Two Apple-rotting Fungi. H. R. X. D'AETH.

Bramleys Seedling apples were inoculated with *Sclerotinia fructigena* and *Penicillium expansum* separately, and with a mixture of the two together. The percentage weight of rotted tissue determined for each inoculation was converted to give the mean penetration of the fungus in centimeters. Thus, the rate of rotting could be followed accurately through all stages. The development of the rot was divisible into (1) an "early" phase, in which rotting proceeded very slowly, and (2) a "late" phase, characterized by a uniform high rate of rotting. During the "late" phase the rates of rotting by the mixture and by *S. fructigena* were closely similar, and exceeded that caused by *P. expansum* alone. Isolations from mixed rots showed that the growth of *P. expansum* was the same in tissue previously rotted by *S. fructigena* as in normal apple tissue. With *P. expansum* the "early" phase lasted about as long as with *S. fructigena;* the "early" phase of the mixture was shorter than that of *S. fructigena* at 10° C., and longer at 15° C., indicating a complex reversible interaction.

Reduction of Bordeaux Mixture Injury by the Use of Amendments. ROBERT H. DAINES and WILLIAM H. MARTIN.

Tests have been conducted during the past season in which amendments have been added to a 1–3–50 Bordeaux mixture to render it less injurious to apple foliage and fruit (Golden Delicious variety). Three types of amendments were used: (1) metals above copper in the electro-motive series were used to reduce soluble mobile copper to metallic copper; (2) zinc sulphate was used to reduce the solubility of the copper in the Bordeaux films; and (3) a wettable sulphur was used to increase the loss of copper caused by weathering.

Copper analyses of foliage were made at regular intervals to determine the influence of the amendments on the adherence of the copper in the Bordeaux films. The metals referred to in Group 1, reduced foliage and fruit injury from a trace to as high as 75 per cent without increasing the loss of copper from the foliage by weathering. The representatives of Groups 2 and 3 reduced the adhesiveness of the copper in the Bordeaux films to a certain extent, and proved only slightly effective in reducing copper injury.

Nitrogen Supply of Sugar Beets in Sand Cultures in Relation to Extent of Injury by Southern Sclerotium Rot. A. E. DAVEY.

The work here reported attempts to test for presence or absence of resistance to attack of *Sclerotium rolfsii* in sugar beets as a result of differential nitrogen supply

to beets grown in mineral nutrient solution in sand culture. The nitrogen supply was varied by depriving the culture solution of nitrogen (ammonium nitrate) after different periods of development of the beets in the several lots. After heavy inoculation the time required for the disease to cause permanent wilting was in general shorter for the low nitrogen groups. Examination of the lifted roots showed that neither the depth of necrotic tissue at point of inoculation nor the superficial necrotic areas of the roots were greater in low than in high nitrogen groups. The difference in time required for wilting was apparently due to the longer time required to involve the absorptive roots in the larger beets in the high nitrogen group. It is possible that the extreme conditions of inoculation may have obscured real differences in susceptibility operating under field conditions.

Cultural Identification as a Necessary Supplement to Tree Decay Studies. ROSS W. DAVIDSON, W. A. CAMPBELL, and DOROTHY J. BLAISDELL.

Cultural identification studies conducted during the past 3 years in connection with stand-improvement operations of the Civilian Conservation Corps have revealed unusual and little-known fungi to be the cause of considerable decay in trees. The more important ones isolated include *Stereum gausapatum, Polyporus compactus, Poria andersonii,* and *Corticium lividum* from oaks, *Polyporus glomeratus* from maple and *Stereum murrayi* from birch. The following characters based on an extensive reference collection of authentic cultures are used in the identification of organisms isolated from decayed trees: (1) Growth rate at different temperatures; (2) color and texture of mycelial mat; (3) fruiting in culture; (4) odor; (5) oxidase reaction; (6) microscopic appearance.

The identity of the organisms responsible for decay in living trees is basic to the application of intelligent methods of control. Identification by means other than cultural comparison is subject to doubt because many wood-inhabiting organisms cause similar types of decay, sporophore production is rare in the majority of heart-rotting organisms, and several different organisms may be present in a single tree.

The Cercospora Leaf Spot of Rose Caused by Mycosphaerella rosicola. B. H. DAVIS.

In the study of cercospora leaf spot of rose, conducted at Ithaca, New York, an ascigerous stage was found in overwintered leaves. Single ascospore isolations and inoculations proved this to be the perfect stage of *Cercospora rosicola* Pass. This stage has characteristics of the genus Mycosphaerella, but unlike any described species. The combination **Mycosphaerella rosicola** (Pass.) comb. nov. is proposed. Only species and varieties of Rosa are known to be affected. The range and symptoms of the disease are given. The pathogenicity is proved by inoculation experiments.

Although 9 names have been applied to species of Cercospora on rose, a comparative study shows only two distinct species among them. These are *Cercospora rosae* (Fckl.) v. Höhn., which is unknown in the United States, and *Cercospora rosicola,* which is world-wide. Among specimens deposited in the Cornell University herbarium, a specimen of a Cercospora, collected at Savannah, Georgia, was found that is distinct from the two mentioned above. Additional material was obtained from Florida. This species, known only in the southern States, is given the name **Cercospora puderii** nov. spec.

Some Disease Developments in Forest Nurseries. W. C. DAVIS, D. H. LATHAM and GEO. Y. YOUNG.

Expansion in forest and erosion-control planting has resulted in special attention to nursery diseases, with active cooperation between the Bureau of Plant Industry, the Forest Service, and the Civilian Conservation Corps. In 1936 the heaviest losses resulted from drouth and heat. A permanent needle droop of red pine, similar to an undiagnosed condition prevalent in the Lake States in 1935, has attended drouth injury in Maryland

and been produced experimentally in the greenhouse by withholding water. The droop effect apparently results from collapse of recently grown tissue at the base of the needle. Deficiency troubles, relieved in different cases by the application of iron, nitrogen, or phosphorus, were observed; purple discoloration of all but the bases of the terminal needles characterized the early stages of the phosphorus deficiency in pine. Use of chicken manure on red-pine transplants was directly correlated with an epidemic of root rot associated with *Fusarium moniliforme*. A Phytophthora resembling *P. parasitica* fruited luxuriantly on killing lesions on black-locust stems up to $\frac{1}{4}$ inch in diameter.

Seed Treatment in Relation to Sand Culture of Seedlings. A. A. DUNLAP.

Seeds of a number of different flower and vegetable plants were treated according to the usual chemical and hot-water methods. These were planted, together with nontreated seed, in washed sand (plus nutrients) and in treated and nontreated soil. In sand, beneficial results were obtained from treatment of the seed only in certain exceptional cases. Injury to germination or to seedling growth sometimes resulted from treatment. Seed treatments for cabbage and Kochia have been found desirable. Seeds of most of the species investigated require no treatment under sand culture, to prevent damping off.

Corticium Disease of Turf. L. E. ERWIN.

Corticium disease was first found in Rhode Island in 1932. There seems to be little difference in susceptibility of colonial, creeping, and velvet bents to this disease. Temperature studies show that *Corticium fuciforme* has a temperature range between 8 and 30° C. The optimum temperature for maximum growth lies between 18 and 20° C. Experimental tests, conducted with a number of commercial products, showed that good control could be obtained with either inorganic or organic mercuries.

Environmental Conditions Influencing the Development of Tomato Pockets or Puffs. ARTHUR C. FOSTER.

Data collected during 4 years of intensive study, under greenhouse conditions, upon the growth of 8 crops of tomatoes under long and short day periods, with different approximate soil moistures, widely different fertilizer formulae, and different temperatures, indicate that tomato pockets may be caused by a number of widely varying environmental factors. It was found that any condition interfering with the normal fertilization and development of the ovules will result in fruit with empty locules or so-called "pockets." When tomato plants are grown continuously in a 60° F. mean-temperature house, with a minimum of 55°, all of the fruits are parthenocarpic with hollow, puffy locules, or typical pockets. Sudden marked changes in the available soil moisture at the time of fertilization of the ovules also leads to sterility and typical pockets. Either excessive soil-moisture or drought conditions during the fertilization of ovules interferes with the normal development of the placental area of the fruit and also results in parthenocarpic fruit. Very often a definite easily visible necrosis appears in the placental area, indicating death of these tissues. The same environmental conditions that cause blossom-end rot also may cause puffy tomatoes; in fact, puffiness often appeared as a forerunner of blossom-end rot in these studies.

Environmental Factors Influencing the Development of Blossom-end Rot of Tomatoes. ARTHUR C. FOSTER.

Over a period of 4 years, a detailed, intensive study has been made of such environmental factors as soil moisture, nutrition, and air temperature as may influence the development of blossom-end rot of tomatoes. With widely varying soil-moisture conditions, it was found that maximum soil moisture was more favorable to the development of the

disease than minimum amounts of soil moisture. In fact, plants grown continuously in low soil moisture appear to be resistant to blossom-end rot, due apparently to their hardened condition. Plants grown in optimum soil-moisture conditions will invariably develop the disease after exposure to drought. Fertilizers, especially the amount of nitrogen and phosphate, appear to have a very direct influence on the development of blossom-end rot. Increasing amounts of nitrogen appear to favor the development of the disease when other conditions are favorable. Increasing amounts of phosphate appear to have a very marked palliative effect in reducing the disease, even when soil moisture conditions favor its appearance. When other conditions are favorable, temperature does not influence the development of the disease, since it appears frquently at mean temperatures of 65°, 70° or 75° F. Furthermore, neither the water requirement nor the amount of water utilized by the plant has any relation whatever to the appearance of the disease. With increasing amounts of nitrogen fertilizer, the plants become more economical in the use of water, but appear to be more susceptible to the disease.

Factors Affecting the Prevalence of the Spotted Wilt Virus. M. W. GARDNER, C. M. TOMPKINS, and H. REX THOMAS.

Certain localities apparently function as endemic centers or foci of infection from which there may be considerable spread by thrips of the spotted-wilt virus in the spring and summer. These localities are characterized by mild winters, no summer rainfall, and the presence of living host plants throughout the year. Apparently, the thrips are active in these centers throughout the year, but the virus is least abundant just after the winter rains, possibly because of a reduction in the thrips population. Besides certain ornamentals and winter crops, certain common winter weeds, such as mallow and chickweed, may harbor the virus. There is no indication that the virus is harbored in the native vegetation of uncultivated lands, as is the curly-top virus. Occurrence of the disease in regions remote from foci of infection is often traceable to introduction of the virus with imported transplants. In localities where the virus is prevalent, a lower percentage of infection occurs in celery, celeriac, spinach, peas, endive, and chicory than in tomatoes, peppers and lettuce, and no infection has been observed in onions, rhubarb, beets, and sugar beets, chard, globe artichoke, carrots, parsley, beans (Phaseolus), crucifers, or cucurbits. Potatoes, though susceptible, also appear to escape infection.

Evaluation of the Geneva Experiment on Scab Control. W. O. GLOYER.

For 7 years lime-sulphur solution (1–40) has been applied to Ben Davis trees in a series of sequences in order to evaluate either a single or a combination of sprays. The effect of the scab fungus and the fungicide were studied in relation to yellow leaf, frog-eye, defoliation, blooming, dropping of fruit, yield, resistance, and related subjects. In the present paper the scab problem only will be considered. The data appear to justify some reconsideration of the concepts of scab control. Overwintering conidia were found to play a greater part in the initial infection than is generally believed. Dormant branches, forced and incubated in the greenhouse, showed conidia infection of the scale leaves. A heavy rain (one-half inch or more), in the delayed dormant stage, apparently favors spread of overwintering conidia. Scab was controlled by 3 applications when spraying operations began either with the delayed dormant, pre-blossom, or calyx spray. The fungicide in the cover sprays prevented autumn infection on the under side of the leaves.

Breeding Disease-resistant Chestnut Trees. ARTHUR HARMOUNT GRAVES.

In order to replace the now nearly extinct American chestnut (*Castanea dentata*) with a disease-resistant, tall-growing type, the Brooklyn Botanic Garden has been cross-

ing various species and hybrids of Castanea during the past 7 years. At the present date nearly 200 hybrids, consisting of various combinations, of which 20 are new to science, are growing in the plantations. The best of these, at the end of its 5th year of growth, is nearly 15 feet high. A method is described for measuring the degree of disease resistance of each individual.

Control of Club Root of Crucifers. C. M. HAENSELER.

Studies on the control of club root (Plasmodiophora brassicae) of crucifers, conducted annually since 1927, indicate that the disease may develop in soils showing a pH of 7.5 to 7.8 for composite samples. A total of 11,000 lbs. of hydrated lime per acre, applied over a 4-year period and giving a soil reaction of 7.5 to 7.6, gave only 73 per cent healthy plants.

Studies of micro-soil samples after 8 years of liming showed that a soil with a pH of 7.87 for composite samples contained small local areas ranging in pH from 5.73 to 8.45. This uneven distribution in soil acidity may account for the failure to obtain perfect control in soils showing high pH values for composite samples.

Calcium cyanamide, used alone, failed to give adequate club-root control on an acid soil but aided when used in conjunction with lime.

Metallic mercury mixed with fertilizer and applied 2 inches below and 2 to the side of the seed at rates equivalent to 8.3 and 16.6 lbs. Hg per acre of 24-inch rows, reduced club-root infection to 10.0 per cent and 5.1 per cent, respectively, compared with 17.0 per cent when fertilizer alone was used.

Cercospora Leaf Spot of Calendula. J. G. HARRAR.

A leaf spot of *Calendula* spp., first noted in 1933, increased in severity in Virginia during the next 2 years. Symptoms of the disease were characteristic of a Cercospora leaf spot and typical Cercospora spores were regularly isolated from leaf lesions. No published study of the disease has been found in the literature, but it has been observed and reported on at least 4 different occasions. The earliest report was that of Saccardo, in 1898, and at that time he named the parasite *Cercospora calendulae*. Experimentally, it was determined that the fungus attacks host plants when they are 4 or more weeks of age, gaining entrance through the stomata. The disease progresses rapidly, frequently resulting in total destruction of the host plant prior to flower production. Infection from air-borne and soil-borne inoculum has been demonstrated, but there is no evidence that the organism is seed-borne. Varietal tests with 17 varieties of *Calendula* gave no evidence of varietal resistance. Single-spore cultures of the fungus on several media produced abundant mycelial growth, but conidiospores were not formed. Control was obtained with sulphur dust, lime sulphur, Bordeaux, and copper oxide sprays.

Movement of Intracellular Bodies Associated with Peach Yellows. ALBERT HARTZELL.

The movement of intracellular bodies associated with peach yellows was recorded by means of cinephotomicrography. Scenes have been prepared showing these bodies moving in the cells of living peach-leaf-petiole, blossom, and root-hair tissues, as contrasted with healthy tissues in which such bodies are absent or rare. Intracellular bodies similar in appearance were found in the intestinal wall and salivary glands of living infected *Macropsis trimaculata*, the leafhopper vector of peach yellows. These also have been photographed. Similar bodies were not found in corresponding tissue of noninfected leafhoppers. Whether the intracellular bodies in the infected leafhoppers bear a primary relationship to those found in diseased plant tissue or are secondary in nature, was not determined. When infected tissue was crushed on slides and the intracellular bodies were released into the cell juice, those from infected peach-leaf-petiole tissue and from the cells of the intestinal wall of infected leafhoppers showed marked motility. Whether the

movement of the intracellular bodies observed is due to vital activity or to purely physical forces has not been determined.

Histological Studies of Infection and Sporulation of Peronospora tabacina in Tobacco Seedlings. R. G. HENDERSON.

On tobacco seedlings growing in the greenhouse, spores of *Peronospora tabacina* germinate on the surface of the leaves and penetrate the epidermis directly. The end of the germ tube comes in contact with the leaf surface and usually forms a slight enlargement that might be called an appressorium. A small hyphal strand is then pushed through the upper wall of the epidermal cell. Within the epidermal cell, an enlarged hypha develops that usually sends out haustoria into the surrounding cytoplasm and also into the adjoining cells. The enlarged hypha continues to grow, or may send out a smaller hypha, until it comes in contact with the inner cell wall where again it forms an enlargement and passes through the cell wall by means of a small hyphal strand into the intercellular spaces of the mesophyll. In a similar manner the germ tube may penetrate a cell of a leaf-hair and the hypha pass from cell to cell until it reaches the mesophyll.

Conidiophores arise from stomata on either surface of the leaf, but under average moisture conditions are confined to the lower surface. Conidiophores bearing conidia have been observed completely imbedded in the spongy parenchyma.

Inheritance of Plant Characters and Resistance to Fire Blight in Pear. E. M. HILDEBRAND and S. L. HSIONG.

It is generally recognized that the most promising method for combating fire blight in pears is the breeding of blight-resistant varieties. In an attempt to find a basis for pear improvement and disease resistance, the writers have examined the pear-breeding material at the New York Experiment Station at Geneva where reciprocal crosses had been made of a number of standard varieties. In examining the plant characters of the parental varieties and of the F_1 hybrids it was found that the maternal parent usually exerted the most important influence on the offspring. This was evidenced by the manner in which certain plant characters as leaf size and serration, fruit quality and stem thickness were transmitted and suggests the need for careful study of reciprocal crosses. The transmission of certain plant characters in the more blight-resistant varieties, Kieffer and Seckel, to their offspring was found correlated with the transmission of blight resistance measured by the percentage of positive inoculations and the length of blight lesion produced. Further study on the inheritance of plant characters in pear is necessary to the determination of the more exact relationship to blight resistance.

Hereditary Factors Affecting Tobacco-mosaic Disease in Solanaceous Plants. FRANCIS O. HOLMES.

In 3 solanaceous genera, Capsicum, Browallia, and Nicotiana, recent hybridization experiments have given new information regarding genes associated with necrotic-type *versus* mottling-type response to infection with tobacco-mosaic disease. In *Capsicum frutescens* an allelomorph of 2 previously reported disease-response genes controls a partially dominant necrotic-type response characterized by imperfect localization of virus. In *Browallia speciosa* a single dominant gene restricts virus to the site of inoculation and allows recovery by abscission of leaves bearing necrotic primary lesions; in some individual plants there is evidence of a second dominant gene, indistinguishable in effect, but segregating independently with respect to the first. A dominant gene for necrotic-type response originally found in *Nicotiana rustica*, and recently reported to have been transferred to a strain of *N. paniculata* by repeated crosses with this species, with subsequent self-pollinations, has now been carried from the necrotic-type strain

of *N. paniculata* to plants of 3 successive generations of hybrids with *N. tabacum*. A similar gene has been carried from *N. glutinosa* to 3 generations of hybrids with *N. tabacum*.

Effect of Copper Sprays on Ripening of Tomatoes.[1] JAMES G. HORSFALL, R. O. MAGIE, and C. H. CUNNINGHAM.

The ripening of tomatoes sprayed with 4–4–50 Bordeaux mixture seems to be delayed. The cumulative yield curve lags. The current explanation for this delay is that diseases defoliate nonsprayed plants, letting in the sun, which accelerates ripening. In the South, where the season is long and diseases usually are serious, the detrimental effects of Bordeaux are counterbalanced by disease control. In the North, with short seasons, the injurious effects usually overshadow beneficial ones. Studies on the development of individual blossoms on test plants in greenhouse and field give the following information: (1) The "delay of ripening" occurs in absence of defoliation diseases; (2) The major factor seems to be that Bordeaux kills young blossoms and thus causes the yield curve to lag; (3) Stunting of young plants by Bordeaux may delay blossoming and reduce setting of blossoms; (4) Time interval between blossoming and ripening is unaffected by spraying, at least in absence of blight; (5) Cuprous oxide of equal copper content is less detrimental to young plants and blossoms than Bordeaux and hence produces less yield reduction; (6) Addition of cotton-seed-oil emulsion to cuprous oxide spray reduces its phytocidal action and tendency to reduce yield.

Studies on a Ring-spot Type of Virus of Tomato. E. P. IMLE and R. W. SAMSON.

A tomato disease characterized by intricate patterns of brown necrotic rings and lines on young leaves, broad, sunken, necrotic streaks on petioles and stems of young shoots, necrosis of shoot terminals, and often corky brown necrotic rings on green and ripe fruits, occurs in many sections of Indiana. The symptoms suggest the name tomato ring spot. Infected tomato plants seem to recover from the disease but retain the virus in infectious form. High temperatures increased the severity of the disease. Mechanical transmission of the virus was best effected by using carborundum abrasive. Mechanical transmission from tomato to Jimson weed was easily effected, but transmission back to tomato was possible only by grafting, or by passage from Jimson weed to tobacco and thence to tomato. A thermal death point of 56° to 58° C. for 10 minutes has been established. Twenty-one to 27 hours aging *in vitro* at room temperature inactivated the virus. Dilutions of 1: 500 rendered the virus completely noninfectious. The tomato ring-spot virus has beeen transmitted to and recovered from 14 solanaceous species and one species in the Amaranthaceae.

Aerial Bacterial Strands in Fire Blight. S. S. IVANOFF and G. W. KEITT.

Aerial bacterial strands on pear blossoms, young fruits, and shoots inoculated with *Erwinia amylovora* were observed and subsequently repeatedly produced experimentally in the greenhouses and the field in the spring of 1936. These strands are hair-like, more or less curved, usually colorless and glistening, and composed of cells of the blight pathogen bound together by a cementing substance. Their length varied from a fraction of a millimeter to several centimeters, their width from 8 to 45 μ. They disintegrate in glycerine slowly and in water instantly, releasing a great number of viable and infectious bacteria. They appear to be a special form of the well-known bacterial exudate, their component materials originating in the internal diseased tissues and emerging at the surface through minute openings. They are easily broken off and disseminated by the wind. Their rôle in the epidemiology of fire blight is yet to be determined.

[1] Cooperative investigation between the Agricultural Experiment Station, Geneva, N. Y., and the Cuprocide Fellowship of the Crop Protection Institute.

Experimental Spraying for Combined Control of Apple Scab and Fire Blight. G. W. KEITT and J. B. CARPENTER.

The following materials were used, with or without supplements: Bordeaux, 2–6–100; Coposil, 2 to 4–100; copper oxalate, 2 to 4–100; copper phosphate-lime-bentonite, 4–8–4–100; Cuprocide, 1½–100; lime-sulphur, 2–100; lime-sulphur, 2–100, with Bordeaux, 2–6–100, substituted in applications 1, B, and 2; lime-sulphur, 2–100, plus hydrated lime, 4–100; and lime-sulphur, 2–100, plus ferrous sulphate, 2 to 4–100. The applications, adapted to the unusual season, were: (D) delayed dormant, (1) open cluster, (B) full bloom, (2) petal fall, (3) 10 days later, (3A) 25 days after 2. Each material was used on at least two plots, each containing approximately 24 20-year-old Wealthy trees in the "off-year," about one-third in full or partial bearing. There was moderate blossom blight, little twig blight. Lime-sulphur gave no blight control: lime-sulphur plus supplements, little. The 12 copper-sprayed plots averaged about one-fifth as much blight as the 8 sulphur-sprayed. The mixed program was as effective as any. Little russeting occurred. There was not enough scab for satisfactory test of its control. The results indicate possibilities for a combined scab and blight spray program, but do not justify recommendations.

Eradicant Fungicides in Relation to Apple-Scab Control. G. W. KEITT and D. H. PALMITER.

In small-scale fall-spraying experiments, an application of certain copper-lime-arsenite sprays to apple trees reduced the incidence of perithecia of *Venturia inaequalis* the following spring by 99 to 100 per cent, without serious host injury. A spring application of a pound-to-gallon aqueous solution of ammonium sulphate to overwintered apple leaves on the ground killed the mature ascospores of the scab fungus and prevented its further development. Effects of eradicant treatments on scab epidemiology were studied. In an orchard, fall-sprayed with copper-lime-arsenite mixtures in 1935, overwintered leaves averaged 5 perithecia per square inch, compared with 255 in a similar nonsprayed orchard some 300 feet away. Neither orchard was summer-sprayed in 1936. Counts showed the following percentage reductions in the incidence of scab lesions per leaf or fruit in the fall-sprayed orchard, based on comparative data from the unsprayed: *leaves*, Wealthy, June 2, 99, July 6, 87; Northwestern Greening, June 4, 94, July 9, 85; *fruit*, Wealthy, July 10, 87, Sept. 2, 75. At harvest, Sept. 2, the untreated orchard had 99 per cent of Wealthy fruit scabbed, the treated 55. Northwestern Greening bore insufficient fruit for counts.

The Use of Movies in Teaching Symptoms and Control Measures of Cabbage Diseases. KIRBY, BURKE and BAUER.

Contaminated Soil in Relation to the Epiphytology of Tobacco Mosaic. S. G. LEHMAN.

Studies are being made to determine the relation of contaminated soil to the epiphytology of tobacco mosaic. Four plots were laid out in a field of Norfolk sandy loam. Two of these plots were in tobacco in 1935, approximately 100 per cent of the plants having mosaic. The entire crop of diseased tobacco was disked into the land at the end of the growing season. The other 2 plots were in corn in 1935. Mosaic-free tobacco plants were set on all the plots in 1936. Up to topping time, no mosaic appeared on the tobacco where corn had grown. Only 0.65 per cent of the plants became diseased where the mosaic tobacco had grown. Some additional mosaic developed after topping. It is believed that the greater part of this resulted from accidental handling of a diseased plant in topping.

These results are in harmony with others already published and confirm the belief of the writer that only a very small percentage of tobacco plants becomes diseased as the result of the direct passage of mosaic into the plants from the soil, even though the soil be heavily contaminated.

Crown Gall on Nicotiana glauca and Nicotiana langsdorffii and the Spontaneous 'Tumors' of Their Hybrid. MICHAEL LEVINE.

Nicotiana glauca and *Nicotiana langsdorffii* do not respond with the same vigor to the tumor-inciting activity of *Bacterium tumefaciens.*

Inoculation of the crown of *N. glauca* induces large, massive, benign overgrowths that remain active for many months. *Nicotiana langsdorffii* inoculated with *B. tumefaciens* produces small tumors that do not live for more than 2 or 3 months. Microscopical studies of these overgrowths show the characteristic histological structure of crown gall.

Spontaneous tumor-like structures on stems and roots of the hybrids derived from crossing *Nicotiana glauca* and *N. langsdorffii* have been studied. Macroscopically, some of these overgrowths in their early stages of development have the appearance of crown galls. Microscopically, these growths differ from crown gall in that they are composed of numerous *anlagen* of stems and leaves. The growths that appear on the upper branches of the plants consist of proleptic shoots, many of which are fasciated. The growths are not invasive nor do they seem to interfere with the life of the plant. These so-called spontaneous tumors of this Nicotiana hybrid are organoid and are comparable with teratomas in animals.

A Growth Hormone in the Development of Crown Gall. S. B. LOCKE, A. J. RIKER, and B. M. DUGGAR.

Tomato plants inoculated with a virulent strain of *Phytomonas tumefaciens* exhibit, in addition to gall development, responses that indicate the presence of a growth hormone in greater concentration than is present in similar, but noninoculated, plants. These responses include (1) increased epinasty of leaf petioles, (2) increased initiation of root primordia on the stem, (3) stimulated cambial activity, (4) inhibited development of axillary buds, and (5) delayed formation of an abscission layer in petioles of senescent leaves. When an attenuated culture was introduced into tomato stems, gall development was much less when growing tips, or expanding leaves were absent than when they were present. Crown galls induced by a virulent culture had an effect similar to growing tips.

Inactivation of Tobacco-mosaic Virus by Ascorbic Acid.[1] MARY LOJKIN.

The reduced form of ascorbic acid in concentrations as low as 0.03 mg. per cc. can produce complete inactivation of purified preparations of the virus of tobacco mosaic. Inactivation takes place only when the ascorbic acid in the virus solution undergoes oxidation by atmospheric oxygen. Conditions that prevent the auto-oxidation of ascorbic acid or decrease its rate prevent inactivation or decrease the rate of inactivation of the virus, while the addition of copper, which catalyses the auto-oxidation, stimulates the inactivation. The virus remains active when ascorbic acid is oxidized in the absence of atmospheric oxygen by such oxidizing agents as iodine, 2,6 dichlorophenolindophenol, and potassium permanganate.

Dehydroascorbic acid does not produce inactivation of the virus under conditions resulting in inactivation by the reduced form. The virus in the whole juice of tobacco plants is less readily inactivated than the purified preparation.

Tomatoes from healthy and diseased plants, grown under the same conditions, are equal in vitamin C content.

Comparative Properties of Virus Proteins from a Single-lesion Strain and from Ordinary Tobacco-mosaic Virus. H. S. LORING and W. M. STANLEY.

Tobacco plants, *Nicotiana tabacum,* infected with virus derived from ordinary tobacco mosaic by several passages in *N. glutinosa* plants by means of single necrotic

[1] This article was preprinted November, 1936, from Contributions from Boyce Thompson Institute, Vol. 8, No. 4, 1936.

lesions, develop symptoms of typical tobacco-mosaic disease. When these plants are treated by the procedure used for the isolation of virus protein, a crystalline preparation closely resembling that from ordinary tobacco-mosaic virus, but differing in certain respects, is obtained. The single-lesion virus protein has approximately the same crystalline form as the ordinary tobacco-mosaic virus protein, but the crystals are somewhat longer and narrower. The two proteins have the same general properties and the same optical activity and isoelectric point. The virus protein from the single-lesion strain has a higher sedimentation constant than does that from ordinary tobacco mosaic, and is also considerably less soluble under comparable conditions. Both proteins have solubilities characteristic of solid solutions rather than of single homogeneous substances. The results obtained from solubility determinations and from ultracentrifugal analysis indicate that the virus protein from the single-lesion strain is more homogeneous than that isolated from plants infected with the ordinary strain of tobacco-mosaic virus.

An Iris Leaf Disease Caused by **Bacterium tardicrescens** *n. sp.* LUCIA MCCULLOCH.

Affected leaves show translucent spots of irregular shape and usually of considerable area. In severe infections the lesions coalesce and cover the entire leaf. In early stages they are dark green, by reflected light, later turning yellow to brown. A period of continued moist weather appears to be essential for serious infection. Under dry conditions infection fails entirely or results in small, inconspicuous spots. Rhizomes are not affected.

The bacterial nature of this disease has been established by the usual methods of isolation and inoculation. The organism is a rather difficult subject for study because of its slow and often erratic growth both in the host and in culture media. On culture media the growth is yellow. The bacteria are motile by means of a single polar flagellum; have inconspicuous capsules; are Gram-negative; and are not acid-fast. Various other characters definitely separate the organism from described pathogens. Because of its slow growth the name, *Bacterium tardicrescens* is suggested.

Isolation of Pathogenic Variants from Pure Cultures of Bacterium stewarti. GEORGE L. MCNEW.

Differences in pathogenicity of pure cultures of *Bacterium stewarti* have been determined by the average number of necrotic lesions per leaf produced by inoculation of 10-day-old Golden Bantam sweet-corn plants. Pathogenic strains derived as single-colony isolates from sparsely seeded dilution plates of pure cultures and from inoculated plants have been studied.

Although a pure culture did not change appreciably in regard to pathogenicity within a year, variants were derived from it by single-colony isolation, which included types both more and less virulent than the parent culture. Two of these variants, which repeatedly gave 0.02 and 1.00 lesion per leaf in inoculation tests extending over a period of one year, in turn gave other variants by single-colony isolation. Variants with all degrees of pathogenicity were isolated from inoculated plants. The majority of the variants isolated from a plant inoculated with a virulent strain were similar to the strain used for inoculation. The proportion of extreme variants from this virulent culture was decreased by host passage. The majority of the variants isolated from a plant inoculated with a weakly pathogenic culture was more virulent than the original culture.

Didymellina poecilospora, n. sp., a Semiparasitic Heterosporium on Bulbous Iris. FRANK P. MCWHORTER.

The overwintering foliage of bulbous iris in the Pacific Northwest is frequently discolored by a Didymellina that forms a conidial stage entirely distinct from *Heterosporium gracile*. This species forms conidia abundantly only in newly infected leaf

areas. The conidial stage soon ceases and is followed by abundant development of perithecia. The black discoloration of the leaves is due to the profuse perithecial formation. Perithecial structures are identical with *Didymellina iridis* except for size. Ascospores average $6 \times 25\ \mu$. Conidial stage a very variable Heterosporium. Conidia on host $6–9 \times 12–38\ \mu$, typically bicellular. In wet weather, on host or in damp chamber or agar cultures, the conidia proliferate and assume a Cladosporium habit. The name **Didymellina poecilospora** is proposed for this mildly parasitic species, which should not be confused with the virulent *Heterosporium gracile*.

Control of Rhizoctonia with Aniline Dyes. JOHN MONTEITH, JR.

Experiments conducted at Arlington Farm, Virginia, during the past summer indicate that certain aniline dyes afforded effective control of turf diseases, particularly large brownpatch (*Rhizoctonia solani*). Malachite green and crystal violet gave good control. Auramine O controlled the disease but was much less effective than the preceding. Rates varied from $\frac{1}{10}$ to $\frac{1}{2}$ ounce per thousand square feet. The heaviest rates were required when the weather conditions were particularly favorable for the fungus. Promising control of Pythium was observed. The dyes checked dollarspot, but failed to give satisfactory control of severe attacks. The dyes proved less effective than corrosive sublimate applied at equal rates. However, they had a distinct advantage over all the mercury fungicides in causing no injury to grass at the heaviest rates. The color of all of these dyes proved objectionable. They were, therefore, combined in such proportions as to give a dye that closely matched the color of healthy grass. Such combinations did not affect the fungicidal properties of the separate ingredients and, in addition to giving disease control, served effectively to mask all moderate disease attacks.

Comparison of Enzymes in Grown-Gall and Noninoculated Plant Tissue. R. NAGY, W. H. PETERSON and A. J. RIKER.

Certain enzymes found in mature crown-gall tissue and in contiguous noninoculated tissue have been examined. Quantitative determinations of oxidase, peroxidase, and catalase yielded 130, 120, and 160 per cent greater enzyme activity, respectively, in the fresh gall tissue than in the contiguous noninoculated tomato tissue. A more striking difference was found in the tyrosinase content of the two tissues. Fifty cc. of expressed crown-gall juice destroyed in 10 hours half of the tyrosin in 200 cc. of a 0.05 per cent solution. No loss was detected from a similar preparation of noninoculated tomato stem tissue.

A Disorder of Cotton Plants Recently Observed in Louisiana. D. C. NEAL.

A disorder of cotton plants, resembling in certain respects the symptoms caused by some of the mosaic diseases, has been observed at the Louisiana Experiment Station since 1934. The disease has appeared regularly in portions of a 3-acre tract in a soil classified as Lintonia silt loam, the affected plants becoming discernible within 35 to 40 days from time of planting. The first noticeable feature is the appearance of the leaves of affected plants. These are puckered, mottled, and variously distorted in the early stages with necrotic lesions appearing along and between the veins; and later, as the plants approach maturity, they become slightly thickened and ragged at the margins. Fasciation of branches, with reduction in size of involucral bracts and floral buds, also occurs, resulting in the formation of small, unsymmetrical bolls. Shedding of flower buds and young bolls, however, is not characteristically associated with the disorder, as is the case with plants affected with crazy top.

The disease has been observed in several varieties of upland cotton. Efforts to transmit it to healthy plants by injecting sap from various parts of diseased plants were unsuccessful, and negative results also were obtained in top- and in arch-grafting experiments.

Verticillium Wilt of Peppermint. RAY NELSON.

A serious wilt of peppermint is prevalent in Michigan and also occurs in other States. It was first observed in 1924, but the earlier abandonment of large acreages is traceable to this disease. Initial symptoms seen in May or June include: (1) dwarfing; (2) unilateral development of terminal leaves; (3) bronze color in terminal leaves. In July and August infected plants show a typical Verticillium syndrome and succumb rapidly. Premature cutting of affected fields is necessary and results in a low yield of oil. English and American peppermint are very susceptible, but some of the spearmints are resistant. Wilt is caused by a species of Verticillium morphologically similar to *V. dahliae*. Soil moisture has a striking influence on the development of the disease and excessive drainage and droughts have increased its destructiveness during the past 6 years. Good commercial control has been achieved by maintaining a high water table. Work is in progress in an attempt to produce resistant mints by hybridization.

Basal Dry Rot of Gladiolus Corms. RAY NELSON.

A dry rot affecting the basal portion of gladiolus corms has been observed for several years and is increasing in prevalence in commercial stocks. The lesions occur mostly on the first and second internodes but may involve other areas. At first the lesions are small, sunken, round or elliptical with a sharply limited border. By enlargement and confluence the entire basal portion of the corm may become involved. At harvest time the affected areas are dark brown to black, rough and scaly, and penetrate the corm to a maximum depth of about 3 mm. Progress of the decay is checked by drying the corms; decay does not continue unless there is delay in cleaning and curing. Planting infected corms results in poor stands due to failure to form roots or to further decay. Proof of the causal relation of Fusarium to the disease has been obtained in inoculation experiments in the greenhouse and field. Treatment of infected corms with calomel or yellow oxide of mercury, 1 pound to 5 or 10 gallons of water, has given good control.

Blue Stain of Cotton is Due to a Fungus. O. P. OWENS.

Recent studies by the writer have shown that at least one fungus will produce blue stain, thereby sometimes greatly lowering the market value of cotton. A species of Alternaria isolated from cotton affected with blue stain has repeatedly caused the natural blue stain, when it was placed on sterile mature cotton fibers. Staining was produced much more rapidly in cotton taken from apparently mature green bolls, occurring as early as 5 days after the inoculation and continuing until the whole lock was completely blue. Locks of green bolls inoculated in the field showed definite staining 15 days after inoculation. Other locks in the same boll, but not inoculated, finally developed the blue stain after the causative fungus had spread to them from the inoculated locks.

An Undescribed Potato Disease in West Virginia. C. R. ORTON and L. M. HILL.

The disease was first noted in the Appalachian region about 6 years ago, since when it has spread so rapidly as to have become a limiting factor in production in certain districts of West Virginia.

The first external symptoms are characterized by a dwarfing, paling, and upward folding of the terminal leaflets. Within 7 to 10 days the vines wilt and die. The vascular region of the stems, tubers, stolons, roots, and numerous spots in the stem pith turn brown. A discontinuous dendritic necrosis of the stem end of the tuber is characteristic.

An extensive necrosis exists in the phloem and adjacent parenchyma, similar to that in leaf roll and net necrosis, and to a lesser extent in the xylem. A granular de-

posit occurs in the necrotic areas, which sometimes show lysigenous cavities. The vessels are infrequently filled with similar granular material.

The necrotic areas in tuber parenchyma lose their starch; standard tests for lignin and pectin indicate the disappearance of these compounds from the diseased areas. Suberin appears to be found in walls of surrounding cells.

The etiology of the disease is unknown. It does not seem to be transmitted through the tuber.

Studies of Copper-Lime-Arsenite Dusts for Control of Wheat Bunt. D. H. PALMITER and G. W. KEITT.

Potentialities of copper-lime-arsenite dust mixtures for seed treatments were studied in relation to control of bunt. In 5 series of greenhouse experiments these preparations were tested in comparison with commercial copper carbonate and ethyl mercury phosphate dusts. When bunt-infested seed was treated and planted in clean soil, all the dusts used gave practically complete control. When clean or infested seed was planted in infested soil, certain copper-lime-arsenite dusts consistently gave slightly better control than the commercial materials. The copper-lime-arsenite preparations increased the percentage of germination of the wheat seed more than the copper carbonate, but less than the mercurial dust. Limited field experiments at Madison gave results similar to those obtained in the greenhouse. These experiments show that the copper-lime-arsenite preparations have a comparatively high fungicidal value under the conditions encountered.

Marigold Wilt. P. P. PIRONE.

A severe outbreak of wilt on marigolds, *Tagetes erecta,* caused by *Phytophthora* sp. occurred last summer in the metropolitan New York area. The disease first appeared early in June on half-mature plants of the variety Guinea Gold. Conspicuous leaf wilting was visible. An area on the stem extending from the crown to several inches above the soil surface was blackened and sunken. Plants growing under moist conditions exhibited stem discoloration extending into the pith, while those growing in drier soil showed a brownish discoloration, principally in the cortex, with very little infection in the woody parts. Inoculations by wounding stem bases, adding inoculum to soil and to wounded roots produced symptoms typical of the disease. Young plants thus inoculated were killed within 6 days. Half-grown to nearly mature plants succumbed in from 10 to 21 days. Of the varieties of African marigolds inoculated, Guinea Gold was the most susceptible. The causal organism was reisolated in every case of successful infection in the greenhouse. Inoculation of the stem bases in a few of the dwarf marigolds failed to produce infection. A species of Fusarium, often associated with wilt, was found to be nonpathogenic. Under greenhouse conditions control of marigold wilt was readily obtained by steam sterilization of the soil. Several fungicides applied to infested soil also offered some degree of control.

Classification of Lily-mosaic Virus. W. C. PRICE.

Three strains of cucumber-mosaic virus were transmitted to *Lilium longiflorum.* They produced symptoms similar to those of lily mosaic in this host. Virus from diseased lilies, obtained from a commercial grower, was transmitted to *Nicotiana tabacum.* It caused primary necrotic lesions and remained localized, producing only an occasional systemic lesion. On passage from tobacco to tobacco it gave rise to a strain that became systemic and produced mottling symptoms. This passage strain was transferred to *Zinnia elegans,* in which it produced mottling symptoms. Inoculation experiments have demonstrated that zinnia leaves, thoroughly invaded by the passage strain of lily-mosaic virus, are immune from infection with virus of cucumber-mosaic strain 6. It has previously been shown that zinnia leaves mottled by cucumber-mosaic virus, or strains of this virus, are immune from infection with virus of cucumber-mosaic strain 6, and that infection of zinnia plants with viruses unrelated to that of cucumber mosaic

does not protect them from infection with cucumber-mosaic strain 6 virus. It is, therefore, concluded that lily-mosaic virus should be classified in the cucumber-mosaic virus group.

Root Rot of Rice. T. C. RYKER.

A root rot of rice, associated with a species of Pythium, was observed in several localities in Louisiana in 1936. In general, the disease occurred where growth conditions were not satisfactory, principally in alkali spots and in areas where the fertility of the soil was poor. In the alkali spots the plants became chlorotic and the roots decayed rapidly, showing the typical flaccid root tips characteristic of most Pythium root rots. When such fields were drained the plants produced new roots, and many of these survived after the fields were reflooded. In fields showing low fertility, particularly along terraces where the soil was thin, the plants after flooding became stunted and in some instances died. The stunted plants would wilt during the hot part of the day because of the poor decayed root systems, but no chlorosis occurred. Draining these fields did not affect the surviving plants. Some of the plants partially recovered, whether the fields were flooded or drained. Inoculation experiments have not shown the Pythium to be pathogenic when the plants were growing satisfactorily.

Methods and Results of Studying Some of the Factors Involved in Spray Injury of the Apple. F. J. SCHNEIDERHAN.

Seventy-five different applications of most of the common fungicides and insecticides were made with a hand sprayer at 130 pounds' pressure under specially selected weather conditions hitherto considered to be conducive to spray injury. Comparisons of high- and low-pressure applications indicated that high pressure is a predisposing factor to spray injury. A complete history of so-called "sulphur shock" resulting in leaf paralysis and leaf dropping after 25 days was recorded. Delayed action of both copper and sulphur injury was observed. Data on the time factors involved in spray injury during certain weather conditions have been recorded. At a temperature of 105° F. pure water sprayed on apples very susceptible to spray injury failed to cause injury. Observations regarding the time required for complete drying of different fungicides indicate a minimum of 15 minutes under favorable conditions to 3 hours under conditions of high humidity. A study of the physical appearance of fruit russet caused by different spray materials indicates that, with only one exception, russet is essentially the same. A type of russet designated as "black pinhead russet" was typical of Bordeaux injury on certain varieties. All of the copper-containing fungicides caused russet under certain weather conditions. Combinations of lime-sulphur 1–80 and half the usual amount of certain wettable sulphurs cause more sulphur burn than standard amounts of these fungicides used alone.

Basal Decay in Oak Stands of Sprout Origin. BAILEY SLEETH and ELMER R. ROTH.

Extensive field studies in cooperation with forest agencies and Civilian Conservation Corps have been made in the Eastern and Central States to determine the sources and extent of basal decay in oaks of sprout origin, factors contributing to decay, and practices necessary to reduce future decay losses. Basal decay was found to present a greater hazard in sprout trees than in seedlings or seedling sprouts because of the danger of decay being transmitted to the sprout from the parent stump and from dead stubs of companion sprouts. Approximately 25 per cent of the trees examined were decayed, *Quercus velutina* showing the most and *Q. montana* the least infection. *Stereum gausapatum* was determined by cultural studies as the causal organism in over 75 per cent of the cases. Over 90 per cent of the decay was traced directly to the parent stump, the remainder originating largely from the removal of a companion sprout or from a dead standing sprout. Factors

concerned with high and low decay hazard were diameter and height of the parent stump, height of sprout origin, presence of stump wounds, the time and condition of heartwood unions, and the presence of dead stubs of companion sprouts. Certain forest practices that, if followed, should serve to reduce future losses in sprout stands, were indicated.

Studies on the Host Range of Bacterium solanacearum. T. E. SMITH.

Bacterium solanacearum E.F.S., the cause of the Granville wilt of tobacco, attacks numerous cultivated and wild species of plants. The disease is soil-borne and, consequently, the wide host range greatly complicates control by rotation. Since many reports of host species have been based entirely on successful stem inoculations, a study has been made of susceptibility as indicated by this method of inoculation as compared to susceptibility as indicated by growing the plants in a badly infested field. All plants susceptible to natural infection also proved susceptible to stem inoculation, but the reverse was not always true. Out of 61 species tested, 5, including the important legumes, velvet beans, soybeans, and cowpeas, were susceptible to the artificial inoculation but apparently immune from natural infection. These data raise the question as to whether species immune from natural infection can be regarded as host plants.

Relation of Injuries to Infection of American Elm by Ceratostomella ulmi. S. J. SMUCKER.

Infection studies with 5- to 8-foot American elms in the greenhouse indicate that *Ceratostomella ulmi* probably cannot invade the vascular system unless injuries through the bark are present. Numerous attempts to infect young trees with *C. ulmi* by placing the inoculum on uninjured surfaces or in injuries in the cortex of roots, trunks, branches, twigs, succulent shoots, and leaves were unsuccessful. However, infection was readily secured under similar conditions when the inoculum was placed in the following types of injuries extending to the xylem: Tangential knife incisions in the roots, trunks, or branches; wounds made by the removal of wedge-shape chips of bark and xylem from the trunk and branches; split branches; injuries in crotches of twigs; pruning injuries; torn petioles; and needle punctures into the wood of roots, trunks, branches, twigs, succulent shoots, and leaves. There are insufficient data to indicate whether leaf infections are a factor in the natural spread of the disease. Trees inoculated during the period the spring wood was being formed developed external symptoms more rapidly and in a higher percentage of cases than those inoculated late in summer.

Influence of Nutrition on Systemic Development of a Yellow Strain of Tobacco Mosaic. ERNEST L. SPENCER.

Investigations have been continued on the interrelationship between host nutrition and host response to virus infection. Seedlings of *Nicotiana tabacum* var. Turkish were grown in sand cultures and supplied with nutrient solutions in which the nitrogen, phosphorus, and potassium contents were varied in turn. After 4 weeks of nutrient treatment, representative plants were inoculated by rubbing the tip of a leaf situated about half-way up the stem. The inoculum was nondiluted juice from a tobacco plant diseased with yellow tobacco mosaic (Johnson's tobacco virus 6). Growth was measured by recording the green weights of representative plants at time of inoculation. There was no apparent correlation between growth and the time of appearance of systemic infection. However, the time of appearance of secondary or systemic symptoms appeared to be definitely correlated with the nutrition of the host. Plants receiving nutrient solutions deficient in either phosphorus or potassium showed systemic symptoms much earlier than similarly inoculated plants receiving an excess of either phosphorus or potassium. Excess nitrogen brought about no appreciable delay in the appearance of systemic infection.

Seasonal Cycle of Ustilago hordei. V. F. TAPKE.

At least under conditions at Arlington Experiment Farm, Rosslyn, Va., the seasonal cycle of barley covered smut (*Ustilago hordei*) does not coincide with the generally accepted beliefs that barley covered-smut spores remain confined to the smutted heads until threshing; that inoculation occurs at threshing through adherence of spores to the surface of seed, and that the seed-borne spores remain dormant until seeding. At Arlington Farm, spore dissemination begins soon after emergence of the smutted heads from broken areas in membranes that enclose the sori and it continues through the ripening, cutting, shocking, and threshing of the grain. Of the spores that are blown, washed, or otherwise carried to the grain, some eventually come to lie beneath the hulls or send infection hyphae beneath the hulls or both. The positional advantage of sub-hull inoculum to infection of the seedling, in field-inoculated seed, doubtless explains why such seed with a relatively light spore-load, so frequently produces much higher percentages of smutted plants than seed that has been surface-inoculated by blackening with millions of spores. The occurrence of sub-hull inoculum also accounts for the previous difficulties in obtaining perfect control of this smut in plants from field-inoculated seed treated with surface disinfectants.

Laboratory Studies on the Fungicidal Properties of Sulphur. J. J. TAUBENHAUS.

Studies were continued on the fungicidal properties of sulphur when used alone or in combination with various forms of copper and some standard insecticides. The materials were tested in their ability to inhibit germination of spores of certain plant pathogens or saprophytic organisms that cause decay to perishables in transit or storage. It was found, as in previous work, that sulphur alone was highly toxic to the spores of certain microorganisms. In other cases, toxicity of sulphur was benefited by the additions of slight amounts of other standard fungicides. The addition of certain insecticides weakened the toxicity of the sulphur mixtures.

Separation of Actinomyces Isolates Obtained from Scabbed Potatoes and from Soil. C. F. TAYLOR.

A comparative study of Actinomyces isolates from scabbed potato tubers and from soil, using bacteriological methods, leads to the conclusion that separation within this group may be accomplished through physiological tests. Primary separation was based on partial acid-fastness (correlated in those studied with the inability to hydrolyze starch). Within the group of 128 non-acid-fast isolates, the pigment response in the surface ring on brom cresol milk, the presence of nitrites after good growth on Zobell's nitrate medium, the utilization of carbon compounds, the final reaction in milk, and the maximum temperature permitting growth gave separatory differences. Within the small partially acid-fast group (15 isolates), the inability to liquefy gelatine was correlated with microaerophilic growth on nutrient agar shake tubes, and provided separation into two main groups. Succinic, formic, oxalic, and citric acids have been more useful than any other of the 30 carbon sources tested. Through these means the 143 isolates studied were separated into 55 different species. So far, no species names have been applied in this work, since similar studies are being conducted on named species obtained through S. A. Waksman and from Baarn.

Inheritance of Resistance of Barley to an Undescribed Physiologic Form of Erysiphe graminis hordei. J. S. TIDD.

Studies of F_2 and F_3 of 3 crosses between resistant and susceptible barley plants were made in the greenhouse. An undescribed physiologic race of barley mildew, here designated as physiologic race 6, was used as inoculum. The resistance of the 3 resistant parent plants was found in each case to be due to a single main Mendelian factor. (1) In

the cross, Svansota M786 × Hanna C. I. 906, resistance was incompletely dominant, the heterozygous individuals being somewhat less resistant than Hanna and homozygous resistant segregates. (2) In the cross, Featherston C. I. 1118 × Goldfoil C. I. 928, resistance was again incompletely dominant. In the F_2 test, conducted in the late spring in the greenhouse, heterozygous individuals gave a reaction of type 2–3, intermediate between resistance and susceptibility. In the winter, however, heterozygous F_3 plants were more resistant and gave 1–2 reactions. Independent inheritance of the factor pairs for resistance versus susceptibility and 2-row spikes versus 6-row spikes was indicated. (3) In the cross, Arequipa C. I. 1256 × Horsford C. I. 610, resistance was dominant. Independent inheritance of the factor pairs for resistance versus susceptibility and hoods versus awns was suggested.

Reaction of Barley to Two Undescribed Physiologic Races of Barley Mildew, Erysiphe graminis hordei. J. S. TIDD.

The reactions of 85 varieties of barley in the seedling stage in greenhouse studies to 2 new physiologic races of *Erysiphe graminis hordei* were studied. These 2 races are designated as physiologic races 6 and 7. In order to separate races 6 and 1, another barley variety, Heil's Hanna 3 C. I. 682, was added to the list of 4 differentials used by Mains and Dietz in their studies. Races 6 and 7 were tested on seedlings of a number of varieties during the winter and spring under the differing environmental conditions then prevalent in the greenhouse. No marked changes in reaction were shown to either race. Tests of varieties in the maturing stage in the greenhouse showed that such barley plants in the spring were more resistant to mildew than seedlings of the same varieties. Maturing plants in the winter were fully as susceptible as seedling plants of the same varieties.

The Fungicidal Value of Mustard Oils. J. C. WALKER.

In connection with a study of the possible relation of the mustard oil, allyl isothiocyanate, to resistance in certain crucifers to *Plasmodiophora brassicae* Wor. the fungicidal value of a number of volatile sulphur oils upon several facultative saprophytes was determined. Arranged in a descending order of toxicity, the substances studied are as follows: allyl isothiocyanate, phenyl isothiocyanate, methyl isothiocyanate, ethyl isothiocyanate, ethyl mercaptan, methyl mercaptan, methyl thiocyanate, ethyl thiocyanate, allyl sulphide, methyl sulphide, ethyl sulphide. The glucoside of allyl isothiocyanate, sinigrin, has little or no toxic value. The free oil completely prevents growth of *Colletotrichum circinans* when added to Czapek's medium at 30 parts per million, while no effect upon growth was noted upon the addition of 1000 parts or more per million of the oil in the glucoside form.

Increasing Importance of Cabbage Mosaic. J. C. WALKER and R. H. LARSON.

In 1935 and 1936 this disease increased in severity on cabbage, cauliflower, and flowering broccoli in southeastern Wisconsin, especially on late plantings, which were exposed to heavy infestation of cabbage aphid, the insect vector. Various manifestations of mosaic and necrotic patterns on outer foliage were followed commonly by internal "fly speck" necrosis throughout the head. Almost complete dropping of outer leaves reduced yield as much as 40 per cent. Continued abscission of inner head leaves caused an important storage loss and predisposed the tissue to secondary organisms. Seed productivity of affected plants was distinctly reduced in a large greenhouse planting.

Pathogenicity of a Brown Cultural Variant of Ceratostomella ulmi. JAMES M. WALTER and CURTIS MAY.

A study of single-spore isolates of *Ceratostomella ulmi* indicated that the species comprises a wide range of cultural races. Some of the strains appeared to retain their

cultural characteristics through several transfers; others continued sectoring. Variants have been noted among both monoconidial and monoascospore isolates.

Among the isolates recognized, a brown variant strikingly different from the characteristic type has been isolated from diseased trees in the United States and in England. American elms in the greenhouse and English elms growing naturally developed typical disease symptoms after inoculation with this brown variant. The variant was recovered from the inoculated trees in all cases.

Penetration and Invasion of Phymatotrichum omnivorum in Cotton Roots Grown Under Pure-Culture Conditions. G. M. WATKINS.

Roots of cotton seedlings grown in nutrient agar, inoculated with pure culture of *Phymatotrichum omnivorum* became rapidly overgrown with a mycelial weft. Sections of such roots in various stages of invasion show that individual hyphae may penetrate the epidermal cell wall or root hairs. From the epidermis the hyphae grow through and between the cells of the cortex. Sometimes penetration of the host cells is accomplished by means of constricted hyphal tips of the fungus. The hyphae finally penetrate the endodermis and enter the stele, where longitudinal progression has been observed in the various tissues of the vascular cylinder. No definitely organized haustoria have been observed. Invaded cells are finally killed, and in later stages are almost entirely filled with hyphae.

Antiseptic and Disinfectant Treatments of Flowering Bulbs. FREEMAN WEISS.

Because of centripetal growth and frequent absence of wound periderms in surface tissues, flowering bulbs and corms are among the least adequately protected plant organs against pathogenic organisms. An increasing tendency to superficial infections, often eventuating in general necrosis and decay, is experienced in commercial culture of flowering bulbs when long continued in one site. The non-hygroscopic husks and cutinized surfaces of many bulbs introduce special requirements as to wetting, adherence, and penetration by antiseptics or disinfectants. Tests of materials commonly used for seed, soil, and tuber disinfection have been made on flowering bulbs for several years. Some botanical groups show a common toxicity relation with respect to certain chemicals; thus, bulbs of Amaryllidaceae are tolerant of mercury in any form and show vegetative stimulation by some forms; iridaceous bulbs are tolerant of most but not all forms of mercury; most liliaceous bulbs are very intolerant. Soluble copper salts are consistently toxic. Formaldehyde is safe with some mercury-intolerant bulbs; lime-sulphur is a generally safe and often efficient antiseptic. Certain bulbs, intolerant of soluble mercury and copper, were beneficially affected by dipping in suspensions of HgO and Cu_2O in aqueous emulsions of cottonseed and other oils stabilized with soap and other emulsifying agents.

Noninfectious Chlorosis of Perennial Phlox and Its Relation to Phlox Blight. FREEMAN WEISS and THELMA B. POST.

Blighting, without abscission, of the lower leaves is a symptom common to several pathological conditions that may affect perennial phlox. A distinct chlorosis, of virus-like pattern, observed in old phlox plantings, was suspected as a factor in the prevalence of blight under these conditions. Attempts to induce chlorosis in seedlings or other presumably disease-free phlox plants by mechanical methods of virus inoculation and by grafting failed. This chlorosis is not due to aster-yellows virus nor to any virus transmissible mechanically to tobacco, cucumber, or tomato. It appears in small and variable proportions of seed progenies, which explains its relative frequence in neglected plantings where seedlings are allowed to grow. It persists indefinitely through vegetative propa-

gation but symptoms are sometimes masked. Another pathological condition, characterized by rugosity and curling of leaves, proved noninfectious by the methods tried; its occurrence is limited to a few varieties. A third abnormality, manifested in necrotic spotting of foliage not associated with a demonstrable parasite was sometimes fatal within one season, or complete recovery occurred. None of these conditions is now considered a factor in phlox blight, which is attributed primarily to infection by *Septoria phlogis*, and secondarily to root injury by environmental factors such as high soil temperature and desiccation.

Control of Damping Off of Conifers. GEO. Y. YOUNG, W. C. DAVIS and D. H. LATHAM.

In preliminary nursery and greenhouse tests a crude phosphoric acid indicated effectiveness in the control of damping off. Results with a purer grade of the acid have been less satisfactory. Formaldehyde, applied to very sandy soil a week before sowing, seriously reduced emergence of jack pine when it was applied at the rate of $\frac{3}{8}$ fluid ounce per square foot, but not where $\frac{1}{4}$ ounce was employed. With black locust at another nursery both $\frac{1}{4}$ and $\frac{1}{2}$ ounce treatments applied after sowing resulted in decided increase in emergence. Ammonium compounds, as well as nitrates, have increased the damping-off hazard. Nursery-water supplies and sand introduced for covering seed at numerous nurseries, particularly in the central States, were unexpectedly found to cause a marked increase in the pH of the seed beds and thus in the damping-off hazard. Steps are being taken toward the correction of the pH of the water and the finding of more acid sand.

Pea Streak and Its Relationship to Strains of Alfalfa Mosaic. W. J. ZAUMEYER.

Three strains of the alfalfa-mosaic virus, infectious to pea, have been differentiated through cross-inoculation, host reaction, and property studies. The symptoms produced by these viruses on pea are similar to one another except in intensity. Strains 1 and 2 produce a leaf mottling, while strain 3 produces a leaf spotting in addition to a mottling. In 1935 the writer reported on a pea streak as being caused by an alfalfa-mosaic virus. It has since been proved that the pea-streak virus is distinct from the virus of alfalfa mosaic, although the symptoms produced by both on peas and horse beans are somewhat similar. No variety of pea thus far tested has shown resistance to the streak virus, while Horal variety is resistant to the 3 strains of alfalfa-mosaic virus. The host range of the streak virus is very limited, while that of the alfalfa viruses is not. The pea streak virus is infectious at 1–5000 dilution, while the alfalfa viruses lose their activity at 1–3000 dilution. The former is not active after 25 hours' aging, while the latter retain their activity as long as 5 days. The pea streak virus is killed at 65° C., while the alfalfa viruses are killed at 70° C.

DISTRIBUTION AND PREVALENCE OF OZONIUM ROOT ROT IN THE SHELTER-BELT ZONE OF TEXAS

GEORGE L. PELTIER[1,2]

(Accepted for publication July 28, 1936)

INTRODUCTION

For almost 50 years ozonium root rot has been the major disease of taprooted plants in certain areas of the Southwest. All investigators now are agreed that Ozonium has been indigenous to these areas for years, but for the most part its presence is manifested only when native vegetation is cleared off and the land is planted to susceptible crops. The range of Ozonium appears to be increasing each year in proportion to the amount of new land opened for cultivation, not only in Texas but in other areas throughout the Southwest.

This soil-inhabiting fungus attacks a greater number and variety of endemic and exotic plants than any other parasitic organism in this region. Regardless of the continual efforts to control root rot, it yet remains the most destructive disease in the Southwest and is responsible for large losses of cotton, alfalfa, and many other important crops, as well as for the death of many fruit and ornamental trees. No satisfactory methods of complete prevention have been devised, although its ravages can be inhibited either by planting nonsusceptible fibrous-root crop plants or by clean fallow or through manurial and chemical treatments. Furthermore, no evidence was found in the literature that the fungus has ever entirely disappeared from an infested area.

In view of the insidious nature of ozonium root rot, it was deemed imperative in advance of planting to map in detail the root-rot-infested areas within the Shelter-belt Zone in southern Oklahoma and Texas, the object being to avoid these areas or to plant resistant tree species. The survey was begun in early June, 1935, when the fungus could be detected in noncropped lands without dependence on susceptible crop plants as indicators of the presence of the fungus. It is the purpose of this report to discuss the methods employed in determining the presence of Ozonium and to offer a preliminary map indicating the distribution and prevalence of root rot in the Shelter-belt Zone of Texas.

[1] Plant Pathologist, Nebraska Agricultural Experiment Station, Senior Botanist, Division of Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture from June 3 to August 2, 1935.

[2] The writer wishes to acknowledge the assistance of Ernest Wright, Associate Pathologist, and F. R. Schroeder and M. M. Evans, formerly Field Assistants, Division of Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture. He also desires to thank F. R. Schroeder for the photographs reproduced in this publication.

DISTRIBUTION OF ROOT ROT IN TEXAS AND THE SOUTHWEST

In 1923 Taubenhaus and Killough[3] reported that ozonium root rot had been found, either by actual field surveys or through diseased specimens of plants sent in for identification, in 67 counties, located principally in east-central Texas. At that time no root rot in the 23 counties in the Shelter-belt Zone had been reported. Eight years later (1931) Taubenhaus and Ezekiel[4] listed 196 counties in which root rot had been observed, either in the field or in plants sent in for identification. Fifteen of the 23 Shelter-belt counties were listed by them as infested with root rot, but no data as to the exact extent of the disease were given for any of these counties.

At first thought it would appear that during the interval 1923–1931, Ozonium had spread rapidly westward from the waxy black lands of central Texas, but more intensive surveys and the extension of agriculture to new land merely revealed that Ozonium, already indigenous, had made itself evident when it attacked susceptible crop plants. A good illustration of this was observed by the writer in the valley of California Creek in northwestern Jones County, where several hundred acres of mesquite land had been cleared the year before, plowed, and planted to cotton in June. At the time this field was visited, the cotton was small, and no root rot was evident; yet, weeds along the fence rows were dying from ozonium root rot; and conidial mats were plentiful on the sides of a road ditch under mesquite trees. It is easy to foresee that cotton cannot be profitably grown for any length of time in this ozonium-infested field.

A preliminary survey of the Shelter-belt Zone in southwest Oklahoma indicated that root rot was prevalent in certain areas in Tillman and Kiowa Counties. From earlier reports it is apparent that the fungus may be found in the two lower tiers of counties to the east and adjacent to the Red River in Oklahoma, since root rot has been noted repeatedly as far east as Miller County, Arkansas. In New Mexico, Arizona, and southern California, root rot has been reported primarily from some of the irrigated valleys. As recently as 1933, Richards[5] found Ozonium causing extensive damage to alfalfa and other susceptible crop plants to Washington County, Utah, in the Virgin River Valley, which empties into the Colorado River above Boulder Dam. Occasional reports also have indicated the presence of root rot in some of the irrigated sections of northern Mexico. Its natural range, therefore, extends from southwestern Arkansas and eastern Texas to southern California, and from southwestern Utah into Mexico.

[3] Taubenhaus, J. J., and D. T. Killough. Texas root rot of cotton and methods of its control. Texas Agr. Expt. Sta. Bull. 307. 1923.

[4] Taubenhaus, J. J., and W. N. Ezekiel. Cotton root-rot and its control. Texas Agr. Expt. Sta. Bull. 423. 1931.

[5] Richards, B. L. Phymatotrichum root rot discovered in Utah. U. S. Dept. of Agr. Bur. Plant Indus. Plant Disease Reptr. 17: 36. 1933. [Mimeographed.]

Judging from the evidence collected by several observers during the past 10 years in many widely scattered localities in the Southwest, it can be definitely concluded that Ozonium is there indigenous, since typical strands of the fungus have been found in desert areas and in virgin lands on the roots of many endemic trees, shrubs, and plants, in some instances without subsequent injury and in others producing injuries sufficiently extensive to cause the death of plants. Where Ozonium is present on the roots of living or dead native plants, root rot usually follows on susceptible crops planted after the land has been cleared. In addition, conidial mats have been observed, where sufficient moisture was present, in strictly desert regions and on non-cropped lands far removed from cultivated areas; and lastly, sclerotia of the fungus have also been found in these same sections.

HOST PLANTS

Taubenhaus, Dana, and Wolff,[6] and Taubenhaus and Ezekiel[7] list upwards of 600 plant species which they have found to be susceptible in varying degrees to ozonium root rot. Roughly, about half of the total number consists of cultivated plants including field, truck, fruit, nut, and berry crops, as well as shade and forest trees, ornamental shrubs, and herbaceous plants, while the remaining half is composed of plants not ordinarily cultivated, such as many of the annual and perennial weeds, and native herbs, shrubs, and trees.

About 41 species of trees and shrubs, most of which are endemic to Texas and Oklahoma, have been recommended as suitable for planting in the Southern Section of the Shelter-belt Zone.[8] These are listed in table 1 on the basis of their reaction to root rot, according to the findings of Taubenhaus and his coworkers.[6, 7]

DESCRIPTION OF THE FUNGUS

The fungus causing root rot may be recognized by 3 distinct stages. There is, first the sterile mycelium (*Ozonium omnivorum* Shear), usually found in the form of buff-color strands, composed of one or more large central hyphae and surrounded by a varying number of small, irregular, thick-wall hyphae. From the more or less triangular cells in the outer band of the hyphae, the characteristic short, upright, acicular hyphae arise. The function of these strands appears to be that of advance mycelia, which spread out

[6] Taubenhaus, J. J., B. F. Dana, and S. E. Wolff. Plants susceptible or resistant to cotton root rot and their relation to control. Texas Agr. Expt. Sta. Bull. 393. 1929.

[7] Taubenhaus, J. J., and W. N. Ezekiel. Check list of diseases of plants in Texas. Texas Acad. Sci. **16**: (1931–32), 5–89. 1933.

[8] Olsen, D. S., and J. H. Stoeckeler. The proposed tree plantations—their establishment and management. *In:* U. S. Forest Serv. Lake States Forest Expt. Sta. Possibilities of shelterbelt planting in the plains region. P. 15–27, 1935.

TABLE 1.—*The relative susceptibility of tree and shrub species, recommended for planting in the Shelter-belt Zone of Texas, to ozonium root rot* (2)

Group and species	Non-susceptible	Highly resistant	Moderately resistant	Susceptible	Highly susceptible
Hardwoods:					
Cottonwood, *Populus* sp.					X
Sycamore, *Plantanus occidentalis* L.		X			
Dwarf Asiatic elm, *Ulmus pumila* L.				X	
Honeylocust, *Gleditsia triacanthos* L.					X
American elm, *Ulmus americana* L.				X	
Russian mulberry, *Morus alba tatarica* (L.) Loud.				X	
Paloblanco, *Celtis reticulata* Torr.		X			
Osage-orange, *Toxylon pomiferum* Raf.	X				
Black locust, *Robinia pseudoacacia* L.					X
Hardy catalpa, *Catalpa speciosa* Warder				X	
Chinese elm, *Ulmus parvifolia* Jacq.				X	
Black walnut, *Juglans nigra* L.				X	
Little walnut, *Juglans rupestris* Engelm.				X	
Green ash, *Fraxinus pennsylvanica lanceolata* (Borkh.) Sarg.			X		
Ailanthus, *Ailanthus altissima* (Mill.) Swingle				X	
Pecan, *Hicoria pecan* (Marsh.) Britt.			X		
Post oak, *Quercus stellata* Wang.				X	
Conifers:					
Austrian pine, *Pinus nigra austriaca* Schneid.				X	
Ponderosa pine, *Pinus ponderosa* Laws.				X	
Arizona cypress, *Cupressus arizonica* Greene				X	
Eastern red cedar, *Juniperus virginiana* L.		X			
Rocky Mountain red cedar, *Juniperus scopulorum* Sarg.		X			
Oriental arborvitae, *Thuja orientalis* L.			X		
Tall shrubs:					
Apricot, *Prunus* sp.				X	
Redbud, *Cercis canadensia* L.				X	
Western soapberry, *Sapindus drummondii* H. and A.					X
Gum elastic, *Bumelia lanuginosa* (Michx.) Pers.			X		
Texas pistache, *Pistacia texana* Swingle			X		
Russian-olive, *Elaeagnus angustifolia* L.				X	
Rough-leaf dogwood, *Cornus asperifolia* Michx.					X
Low shrubs:					
Desert willow, *Chilopsis linearis* (Cavanilles de Candolle)			X		
Tamarisk, *Tamarix gallica* L.			X		
Lilac, *Syringa* sp.					X
Hawthorn, *Crataegus* sp.				X	
Chickasaw plum, *Prunus angustifolia* Marsh.				X	
Sumac, *Rhus* sp.					
Coralberry, *Symphoricarpos orbiculatus* Muench.	X				

through the soil. They are the sole agents responsible for the direct penetration and infection of the roots of susceptible plants. The mycelial weft prominent on the roots of diseased plants is so typical that the fungus can be readily identified with a hand lens, and only in few instances must a microscope be resorted to.

Second, the sclerotia, small, buff, compact bodies varying in size from that of a mustard seed to that of a wheat kernel, in shape from irregularly spherical to oval, and in numbers from several to many, are usually found beneath diseased plants at different levels in the soil. They are produced, in the main, in a bead-like arrangement, from a series of enlargements of the rhizomorphic strands. Like the strands, the sclerotia may remain dormant indefinitely under adverse conditions and resume growth when the proper environmental conditions are at hand.

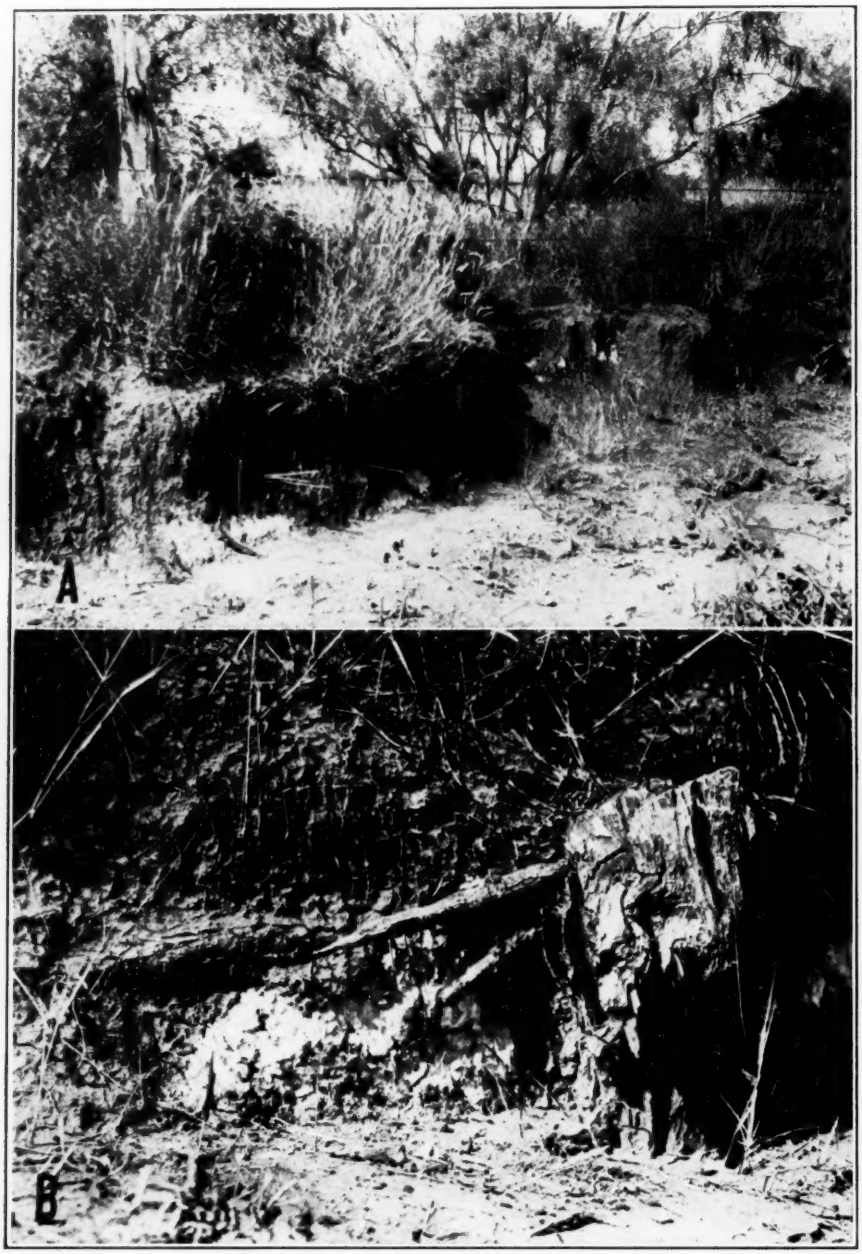
Third, the spore stage, (*Phymatotrichum omnivorum* (Shear) Duggar), which first appears on the surface of the soil in the form of a dense, fluffy white mat of mycelium. The size and thickness of the conidial mats vary with weather conditions. Depending on the duration of cloudy weather with rain, together with a high soil moisture and high relative humidity, the spore mats may become from 1 to 12 inches in diameter. Within 24 to 48 hours after first appearing, the creamy white mycelium is replaced by spores, which in the mass are of a buff color. These conidial mats may appear on root-rot-infested land, either cropped or virgin, at any time during the active growth of the fungus, but only when conditions for their formation are favorable. Although several investigators have obtained a low percentage of abortive germination, none has been able to produce mycelial growth from spores, nor to cause infection of any plant with spore suspensions. Thus, for the present, the conidial stage can be considered functionless.

SURVEY METHODS

Diseased or dead plants were carefully lifted from the soil by means of a tile spade and their roots were examined for the presence of Ozonium strands. If the roots of one or more plants growing on a square mile of land showed the typical mycelial weft, the entire section was, for the purpose of the preliminary survey, considered infested, even though root rot might then have been confined to a small area. Since the formation of sclerotia in the soil can be due only to the presence of Ozonium strands, a limited amount of soil sifting to find the sclerotia was attempted.

Owing to the higher than normal precipitation for the spring and summer months of 1935 in the Shelter-belt Zone, probably a nearly maximum amount of infection by Ozonium occurred on all types of plants and likewise an abundance of conidial mats were produced during June and July. The mats were found under various conditions in a number of counties in virgin and

PLATE I



A.—A series of conidial mats along a road bank, extending for some distance. Weeds infected with Ozonium were present in the mesquite thicket and in the wash at the side of the road.

B.—Conidial mats growing in conjunction with the roots of a mesquite stump. (Haskell County.)

pasture lands and in fields devoted to many kinds of crops (Plate I, A and B). Here again the presence of conidial mats, in the absence of any susceptible plant indicators, on any square mile of land was thought sufficient to classify the section as an infested one.

The susceptible plants examined for Ozonium infestation in virgin and pasture lands consisted of the more common native herbaceous plants, shrubs, and trees, together with annual and perennial weeds growing along the roadside and, in many instances, in association with the above-named types of plants. On areas devoted to nonsusceptible crops, weeds were depended on to a great extent (Fig. 1). On lands cropped to susceptible

FIG. 1.—A diseased white horse nettle growing in a maize field, indicating that Ozonium is present in the soil. (Baylor County.)

plants, such as alfalfa and other legumes, the root-rot spots were more obvious. As cotton was late in this section, root rot was not observed in cotton fields until the first week in July, so that, up to that time, susceptible weeds had to be used as indicators of Ozonium on land devoted to cotton. Garden and truck patches, farm orchards, roadside, city, and farmstead plantings of trees and ornamentals were also checked for diseased and dead plants and the roots examined for the presence or absence of Ozonium strands.

For the most part the greatest dependence was placed on 3 very susceptible weed indicators, present throughout the Shelter-belt Zone, *i.e.*, the nightshades or horse nettles, particularly the white horse nettle, *Solanum*

PLATE II

A typical roadside view of diseased white horse nettle, at the base of the ubiquitous mesquite. A recently cleared field planted to cotton lies beyond the fence. (Haskell County.)

eleagnifolium, the ragweeds, *Ambrosia* spp., and lambs' quarters, *Chenopodium album.* The universal distribution of these 3 weeds in native pasture, cropped, and waste lands, along railroad embankments, roadsides, ditches, washes, on the banks of small dry creeks, and on the overflow areas of the larger streams, aided very materially in delimiting the ozonium-infested areas from the noninfested areas (Pl. II). The cockleburs, *Xanthium* spp., ground cherries, *Physalis* spp., sunflowers, *Helianthus* spp., and thistles, *Cirsium* spp., together with other less common annual and perennial weeds, also served as susceptible indicators in the root-rot survey.

The general procedure in mapping the root-rot-infested areas was briefly as follows: An idea of soil types, location of agricultural lands, contours, and drainage systems, including dry washes, creeks, and larger streams, was obtained from available maps and through consultation with county agricultural agents. All available information regarding relative prevalence of root rot also was obtained from them. On the basis of this information, the county was divided into several districts and a reconnaissance of each district was made. When root rot was first found, either on plants or in the form of conidial mats, an intensive section-by-section survey was conducted until the entire area of root-rot infestation was determined. This procedure was followed in the areas under cultivation, since lack of roads in certain non-agricultural areas precluded anything more than a reconnaissance. Continuity of infested sections, and relative prevalence of Ozonium were determined by the presence of diseased or dying host plants or conidial mats and by the number of host plants attacked by the fungus.

RESULTS OF SURVEY

The distribution and degree of infestation of ozonium root rot, as determined by the survey, is presented in figure 2. During the progress of the survey, and again when the map was being prepared from the data obtained, the writer was impressed with the apparent relationship between root-rot infested areas and the water-sheds and drainage basins of the rivers that have either their source in, or run through, the Shelter-belt Zone. For simplicity, the results of the survey will be discussed on the basis of water-sheds and drainage basins of the larger streams. As no root rot was found in the four northern counties included in the Shelter-belt Zone in Texas, they have been omitted from the figure. A reconnaissance opposite these counties in Oklahoma showed absence of root rot in the drainage areas of the two forks of the Red River and beyond their junction for a distance of 20 miles, with the exception of a localized area about 5 miles along a small tributary in the northwestern part of Tillman County.

In Texas only two isolated spots of root-rot infestation were located in the drainage basin of the Prairie Dog Town Fork. The first consisted of

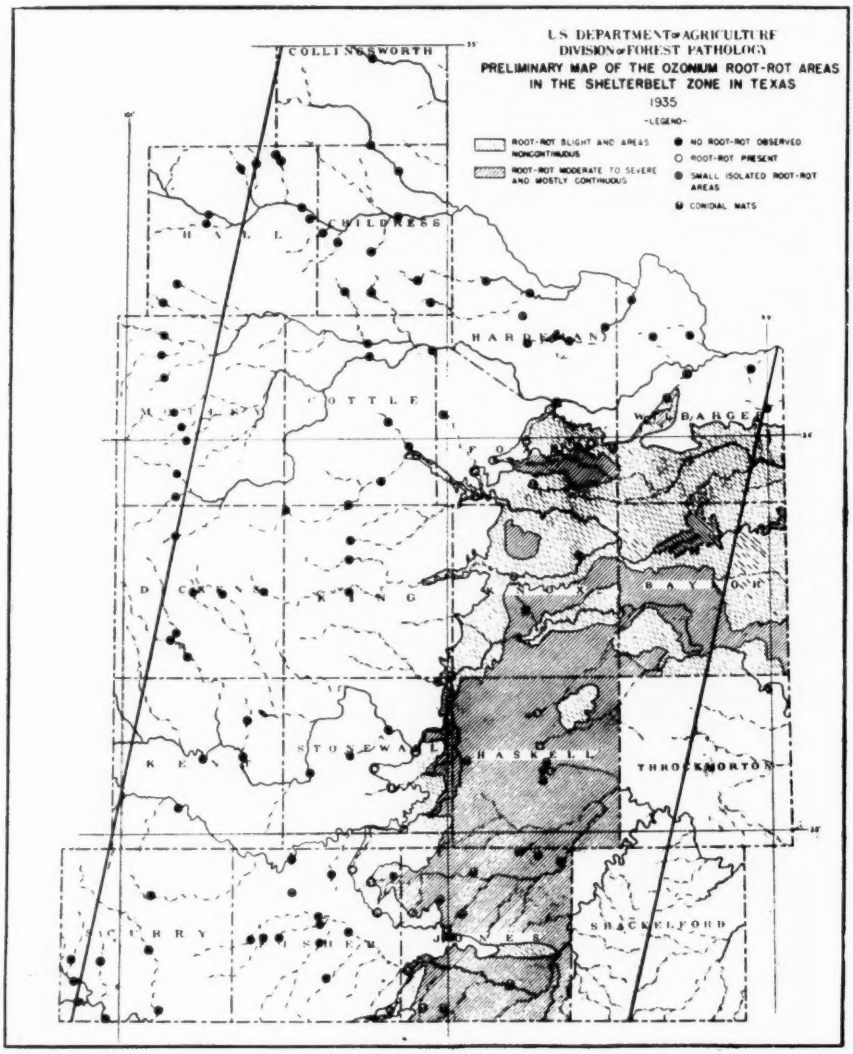


FIG. 2. The distribution and prevalence of ozonium root rot in the Shelter-belt Zone of Texas.

an area equaling four city blocks in the town of Memphis, Hall County, and the second area, approximately three sections in extent, lies three miles west of Quanah, Hardeman County. Since root rot was not found elsewhere in either county, it may be assumed that Ozonium was introduced into these limited areas on infested nursery stock, where it has persisted and gradually spread from one or more foci in the course of years.

The Pease River and the majority of its tributaries have their origin in the western part of the Shelter-belt Zone; this drainage basin covers the greater part of several counties and finally empties into the Red River in northeastern Wilbarger County. Root rot was found at only two points in this large drainage area, in the valley of Raggedy Creek in Foard County and Paradise Creek in eastern Foard and Wilbarger Counties. In the first instance, root rot was found generally distributed throughout the narrow valley consisting mostly of virgin land. Root rot was observed in the larger valley of Paradise Creek attacking a number of field-crop plants, fruit and shade trees and ornamental shrubs, as well as weeds. Conidial mats also were plentiful in late June in alfalfa fields. Both valleys are delimited by sand ridges which restricted the distribution of Ozonium. Apparently root-rot infested areas in the Pease River basin are strictly confined to the valleys of Raggedy and Paradise Creeks and in both instances are sharply delimited by sand ridges.

The entire water-shed of the Wichita River lies within the Shelter-belt Zone and a large part of the area is drained by this river. The most westernly locations of Ozonium-infested land in this basin were found in southeastern Cottle County at a point where the North Fork contains running water for the greater part of the year, in southwestern Foard County on the Middle Fork beyond its junction with the North Fork, and in the valley of the South Fork in eastern King County. Observations beyond these points showed root rot absent.

Ozonium root-rot was noted throughout the area between the North and South Forks of the Wichita River and it was especially prevalent in the agricultural area about Truscott in Knox County. Here the extreme susceptibility of Chinese elms was observed in a young four-year-old grove, where 50 per cent of the trees were diseased, dying, or dead. In Foard County, root rot was distinctly pronounced throughout the course of Beaver Creek, a rather large tributary of the Wichita River.

Only a small portion of the water-shed of the Little Wichita River has its origin in the Shelter-belt Zone. Root rot was especially prevalent, mostly in virgin lands, throughout this drainage basin. Diseased weeds found along the highways and railroad embankments served as the only locations where susceptible plant indicators could be found. This was particularly true in large virgin and pasture areas of northern Baylor and southern Wilbarger Counties.

More than half of the Shelter-belt Zone lies in the drainage of the Brazos River, comprising three large forks, the Salt and Double Mountain whose water-sheds lie beyond the Zone and the Clear Fork draining all or a portion of four southern counties. The western limits of root-rot infested lands in the valleys of these forks were located in the eastern quarter of Stonewall and in the north and southeastern corners of Fisher Counties. The relative

distribution and prevalence of root rot in both virgin and cropped lands in the area between the three forks in these counties, is shown in figure 2. The disease was very prevalent in the entire region between the Wichita and Brazos Rivers in Knox and Baylor Counties and especially so in the better agricultural areas. Even on the divide between these two rivers, many diseased weeds were noted.

There was an area in northeast Haskell County consisting of rough and gravelly land where root rot was noted only occasionally. A noninfected area, made up mostly of sandy soil and probably the former bed of a stream, extends into central Jones County. A small persistent isolated area of ozonium-infested land was found directly west of Rotan in Fisher County, probably the result of introducing infected nursery stock.

Part of the water-shed of the Colorado River is in Scurry County. An intensive survey failed to locate any evidence whatsoever of Ozonium there, in spite of the abundance of susceptible plant indicators. Taubenhaus and Ezekiel (4) have reported root rot in both Scurry and Kent Counties, but the writer was unable to find any evidence of root rot in either county during the growing season of 1935.

On the basis of this preliminary survey the following counties in the Shelter-belt Zone can be safely considered ozonium-free; Lipscomb, Hemphill, Wheeler, Collingsworth, Childress, Motley, and Dickens. If we omit from consideration the 2 small isolated spots in Hall and Hardeman Counties we can include these counties. Although root rot was not observed in Kent and Scurry Counties, there remains the probability that small infested areas are present on the basis of the reports of Taubenhaus and Ezekiel.[4] The greater portions of the land area in Cottle, King, Stonewall, and Fisher Counties also are noninfested, although ozonium-infested areas have been found to varying extent in some of the eastern section of these counties. Most of the land in Jones and Knox and all in Haskell and Baylor Counties may be classified as harboring Ozonium. Approximtely the southern half and the southern third of Foard and Wilbarger Counties can be placed in the same category. No intensive survey was made in Throckmorton and Shackelford Counties, since they consist almost entirely of native pasture lands, but enough evidence of ozonium root rot was seen to indicate that the fungus is generally distributed.

For lack of better landmarks, ozonium root rot in the Shelter-belt Zone may be said to be prevalent as far as 34° N. Latitude and approximately to 100° West Longitude. These limits, however, should be considered as tentative until they are rechecked.

DISCUSSION

The futility of opening native ozonium-infested land to the production of susceptible crop plants is strikingly evident, yet new tracts are being

cleared each year, not only in the Shelter-belt Zone, but in other areas of Texas and the Southwest as well. Through the opening up of large areas of virgin land to cultivation in newly irrigated sections of the Southwest, we may find that much of the value of such projects will be lost through ozonium root rot, so that, almost immediately, only certain nonsusceptible crops can be grown. It is futile, likewise, to plant trees susceptible to Ozonium, either in virgin or cultivated land infested by the fungus, since here again root rot will be one of the limiting factors in the final development of the Shelter-belt project in Texas. Therefore, it is expedient to avoid root-rot areas in the zone, or, if this be impractical, to plant only sufficiently tolerant or resistant trees so that the seedling mortality due to ozonium infection will be slight and a nearly normal growth will occur, in spite of the aggressiveness of the fungus.

Repeated observations indicate that when root rot is found at the headwaters of a stream it usually is distributed throughout the drainage basin, and its incidence increases at the lower levels. Prevalence and continuity of root rot from section to section also is more pronounced in the better agricultural than in the submarginal and virgin lands. This incidence of root rot is, perhaps, the result of an accumulation of the fungus in the better farming areas, due to the continued planting of highly susceptible crops, such as cotton, and the lack of suitable long-time rotations with nonsusceptible crops. By planting trees tolerant to Ozonium, it may be possible to reduce the losses to a minimum in the Shelter-belt plantings.

The writer already has stressed the sharpness with which noninfested areas are delimited from infested. Of the many seen during the survey, 2 illustrations of the condition will be mentioned. The headwaters of Thompson Creek in Jones County, Texas, are encompassed by rather high ridges. No root rot was found to the west and north of this valley beyond the ridges, but, in the valley, conidial mats were observed on the face of the road cuts of the slopes, diseased weeds were plentiful in the mesquite thickets and along the roadside, and diseased cotton plants were noted in the first cultivated field. Similarly, in Tillman County, Oklahoma, the headwaters of Deadman's Creek are located in a semibowl surrounded by high ridges. Here also no root rot was found west of the divide. In the basin, however, Ozonium was noted on the roots of weeds, and conidial mats were found in a shaded area of a roadside ditch. From this point on, down the valley, incidence of root rot increased and cotton was dying in rather large spots in the first cultivated fields. While Ozonium has been seen in all types of soil from blow sand to a heavy adobe, it is apparent that the moisture-holding capacity of a soil is a more important factor than the soil type. Perhaps sufficient moisture seeps into the low basins making up the headwaters of the creeks from the surrounding ridges to perpetuate the develop-

ment of the fungus indefinitely. In this connection the deficiency of soil moisture and possibly low temperatures may be 2 of the contributing factors that limit both the western and northern infestation in the Shelter-belt Zone in Texas and southern Oklahoma. From the enormous amount of soil and plant débris washed down the drainage basins in 1935 in this region, one can readily realize why incidence of root rot increases at the lower levels.

SUMMARY

In view of the insidious nature of the indigenous soil-inhabiting fungus, *Ozonium omnivorum*, the infested areas within the Shelter-belt Zone extending into southern Oklahoma and Texas in advance of planting were mapped with the object of avoiding these areas or employing resistant trees. The susceptible plants employed as indicators of infested lands consisted of the more common endemic herbaceous plants, shrubs, and trees, together with annual and perennial weeds and many crop plants. The universal distribution of 3 susceptible weeds (horse nettles, ragweeds, and lamb's quarters) in virgin, pasture, waste, and cultivated lands, along railroad embankments, roadsides, fence rows, ditches, washes, banks of dry creeks and on flood plains of larger streams, as well as the presence of conidial mats, aided very materially in detecting Ozonium. A section of land was deemed infested when one or more diseased plants revealed the characteristic mycelial weft on the roots, or when conidial mats were found. On the basis of the above procedure the approximate limits of root-rot infestation were found to be south of 34° N. Lat. and east of the 100th meridian. In the main, prevalence of root rot was much more pronounced in the better agricultural lands and in the valleys. Repeated observations indicate that when root rot is found in the headwaters of a stream it usually is distributed throughout the drainage basin, and the incidence of root rot increases at the lower levels. The sharpness with which the infested and noninfested areas were delimited was especially striking.

SOME EFFECTS OF PLANT DISEASES ON VARIABILITY OF YIELDS

CARL HARTLEY AND ANNIE RATHBUN-GRAVATT

(Accepted for publication August 10, 1936)

Plant pathology has been applied with generally recognized success to improving the quantity and quality of plant products and decreasing the cost of production. Another objective, that of reducing the variability of yields, is believed to deserve somewhat more consideration than it has received. Yields of most crops vary unpredictably from year to year, causing troublesome fluctuations in supply and price, increasing the difficulties that beset the agencies wishing to regulate production, and interfering with the security of the individual producer. The variation is, of course, the result of the effects upon yield of numerous factors, which in themselves are variable. It is much influenced by such factors as drouth. The present paper attempts to consider only the contribution to yield variation made by plant parasites and the effect that disease-control measures may have on yield variation.

Two groups of diseases that differ decidedly in their effects on yield variation can be distinguished. The first includes those favored by conditions that weaken the host. These are likely to decrease yields most in years when the crops would be poor anyhow, and thus tend strongly to increase the variation in annual yields. The second includes those favored by conditions that are otherwise favorable to the host; these tend to pull down the production of the peak years, more than that of the poor years, and are, therefore, less likely to increase the yield variation; they may even decrease variation. There are, of course, intermediate diseases, which are as likely to be severe in good years as in poor years, and, therefore, have an effect on variation intermediate between the two groups. Further analysis will be facilitated by use of the customary measures of variation and correlation.

VARIABILITY OF REGIONAL YIELDS AS AFFECTED BY A SINGLE DISEASE

The addition of any independently varying factor necessarily increases the variation in the end results. Fortunately, the variation due to an additional factor is not directly additive to the variation produced by other factors. If the standard deviation of the annual yields of a particular crop were 4 bushels per acre and a new disease appeared causing losses that had a standard deviation of 3 bushels, the standard deviation of yields after the establishment of the disease would be not the sum of 4 and 3, but the square root of the sum of their squares, or 5 bushels.

In actual fact, most diseases are not independently varying factors. Interrelations are the rule. It is scarcely possible to conceive of a disease whose progress is not influenced by the vigor of the host, or by environmental factors that also affect the yield in some other way. The dependence of the disease on conditions affecting the host may be expressed quantitatively in the coefficient of correlation between the disease loss and the yield that would be had in the absence of disease. If disease loss increased as the disease-free yield decreased, this coefficient of correlation would be negative and the effect of the disease in increasing yield variation would be accentuated. Thus, with a correlation $r = -0.5$ between disease loss and the yield to be had without disease in the imaginary example in the preceding paragraph the variation in yield would have been increased by the new disease to 6.1 bushels instead of 5 bushels. A perfect negative correlation would have made the disease variation directly additive, thus bringing the standard deviation of the actual yields to the full 7 bushels. If, on the other hand, the disease losses increased under conditions otherwise favorable for high yields, the correlation between disease loss and yield in the absence of disease would be positive. This would result in a final variation less than that resulting from a disease that was independent of other yield factors, and might result even in a variation smaller than would have occurred in the absence of the disease. Thus, a correlation of + 0.5 in the example would result in a final standard deviation of 3.6 bushels, or less than the 4 bushels that represented the variation before the disease appeared, and a perfect positive correlation would have reduced the total variation to 1 bushel.[1]

To turn from synthetic to actual examples: The variability of the loss factor itself is shown for several important diseases by Faris, Stevens, and their associates (4, 8, 9, 11). The relative variation, and occasionally even the absolute variation, can be higher for the losses than for the yields themselves (Table 1).

Diseases that are negatively correlated with the yield that would have occurred in the absence of the disease, are probably most numerous among

[1] A more complete expression of the importance of correlation in determining the effect of a disease on the variation in annual yield is to be found in the usual formula for computing the variance of a difference. The actual yield is regarded as the difference between the disease-free yield and the estimated loss. The variance of the actual yield is, therefore, expressed by the formula $\sigma_A^2 = \sigma_F^2 + \sigma_D^2 - 2r_{FD}\sigma_F\sigma_D$, in which A is the actual yield, F the yield as it would be if free from the disease, and D the loss caused by the disease. From this it appears that the variation of the yields is always increased by the disease if r is negative; for it to be decreased by the disease, r must be not only positive, but it also must be large or σ_D must be small. For crop-planning purposes it is the coefficient of variation rather than the standard deviation that is important. This coefficient is more apt to be increased by disease than is the standard deviation because a disease pulls down the mean yield. A formula showing the effect of correlation on the relative magnitude of CV_A and CV_F would be complicated.

root rots and vascular diseases for which it is difficult to secure estimates of loss. Some indicative figures are available, however, in connection with fusarium wilt of cotton, which will serve to illustrate the previous generalization. This wilt is a disease for which liberal fertilization to produce more vigorous plants is recommended as one method of control (6), and in which negative correlation might, therefore, be expected. The yield per acre that should have been obtained in absence of wilt was computed for each year by adding the estimated loss to the reported yield. The correlation found between the losses and the hypothetical wilt-free yields for the United States as a whole, for the years 1920–1929 was −0.36; these wilt-free yields have a coefficient of variation of 11.4 per cent; the reported actual yields show a variation of 12.0 per cent. The disease thus appears to have increased the yield variation. Its effect on variation was small because the variation in the estimated losses was small; but the effect on the standard deviation was 14 times as great and on the coefficient of variation nearly twice as great as it would have been in the absence of correlation. It is unfortunate that figures are not available for some negatively correlated disease that produces larger and more variable losses.

Among diseases that flourish with the same temperature, moisture, or other conditions favorable to the host, late blight of potatoes furnishes excellent illustrative material, and in this case the variation of loss is large

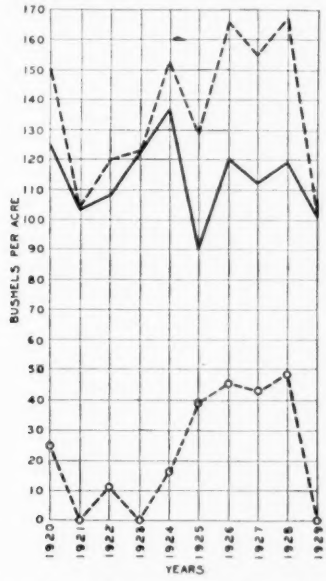


FIG. 1. Apparent effect of late blight on potato yields in New York. Solid line, reported yields. Lower broken line, estimated losses from late blight. Upper broken line, hypothetical blight-free yields.

enough to have a very considerable influence. The estimates for yield per acre in the State of New York for the 10 years studied (Fig. 1) have a standard deviation of 14 bushels. The annual loss estimates have a standard deviation of 20 bushels. But these variable losses, large at times, did not increase the variation in yield during these 10 years; in fact, if one assumes the approximate correctness of the yield and loss estimates, complete disease control would have made the annual yield even more erratic. In figure 1, this is shown by the upper broken line obtained by adding the estimated loss to the reported yield and thus representing hypothetical blight-free yields. It is evident from inspection of the graph that these hypothetical blight-free yields are more variable than the reported yields; their coefficient of variation is, in fact, one and a half times as great.[2]

The explanation is in the high positive correlation between the estimated losses and the hypothetical blight-free yields. The coefficient of correlation is +0.82. In other words, the disease appeared at its worst in those years when the crop would otherwise have been the largest; disease losses, therefore, depressed the high points in the yield curve more than they did the low points. Late blight thus seems to have been actually a stabilizing factor, so far as the total output of New York State during these 10 years was concerned. For 6 of these same years independent disease estimates are available also for Maine and Pennsylvania, the other two eastern surplus late-potato States. The coefficient of variation of the hypothetical blight-free combined yields for all three States during the 6 years was more than one and one half times that of the actual yields. Table 1 gives more complete data for all the States in which the disease was reported as important at some time during the 10-year period studied.

[2] For a disease that causes losses as large as does potato late blight, the principal source of error in the hypothetical blight-free yields, in their coefficient of variation, and in the coefficient of correlation between them and the disease losses, is probably in the inevitable errors of estimate of the losses. No information is available on the accuracy of the estimates, beyond the knowledge that they are made by experienced men as the result of observation on numerous and widely distributed fields. The effect of errors in the case under consideration is probably to increase both coefficients. The diseases-loss estimates, however, are positively correlated with the reported yields, as well as with the hypothetical, so there is little doubt that a positive correlation would be found between disease losses and correctly adjusted hypothetical yields. For brown rot of peach, bunt of wheat, and ear rots of corn, Stevens (9) and Stevens and Wood (11) compared the estimates compiled by the Plant Disease Survey with independent estimates obtained in very different ways, with such generally good agreements as to increase greatly the confidence in the Plant Disease Survey estimates on the visible diseases of aerial plant parts. Even where estimates of damage are entirely correct, it is possible, of course, that if the disease had been absent some other factor might have become important in limiting yield. For example, if control of a leaf spot resulted in a 15 per cent greater area of active leaf surface, a marginal soil-moisture supply might become submarginal.

TABLE 1.—*Variation in yields of potatoes and in estimated losses from late blight, 1920–1929*

State	Number of years represented	Standard deviation of			Coefficient of variation of			Correlation of yield with per cent loss from late blight	
		Reported yield	Estimated loss from late blight	Computed blight-free yields	Reported yield	Estimated loss from late blight	Computed blight-free yields	Reported yield	Computed blight-free yields
		Bu.	*Bu.*	*Bu.*	*Per cent*	*Per cent*	*Per cent*		
Wisconsin	10	15	9	22	15	175	20	.58	.82
Minnesota	10	15	3	17	16	246	17	.42	.58
West Virginia	10	15	12	20	15	174	19	.10	.69
New York	10	14	20	25	12	88	18	.05	.82
Oregon	10	13	3	14	12	171	13	.53	.66
Massachusetts	9	21	21	18	19	140	15	−.67	.35
Maryland	9	19	4	19	18	78	19	.41	.54
Ohio	9	14	5	16	15	183	17	.26	.46
Maine	8	44	3	43	18	104	16	−.45	.23
New Hampshire	8	18	13	21	15	120	16	−.34	.31
Pennsylvania	8	14	19	26	13	110	21	.24	.82
Tennessee	8	13	6	17	19	225	23	.50	.73
Connecticut	7	16	5	16	14	129	13	−.25	.09
Average	9	17.4[a]	9.5[a]	20.8[a]	15.1[b]	142.6[b]	17.2[b]	.13[c]	.60[c]

[a] Weighted arithmetic mean.
[b] Weighted geometric mean.
[c] Weighted mean through Fisher's z transformation.

On the purely theoretical basis given in footnote 1, it is evident that not only potato blight, but any disease of any crop will necessarily have a stabilizing effect on yields if the size and variability of the losses are not too large and disease prevalence is favored by those conditions that are otherwise favorable to high yield. The dependence of the variation effect of a plant disease on the way in which it is correlated is shown graphically in figure 2 for Fusarium on potatoes. For each of the 9 States in which the correlation

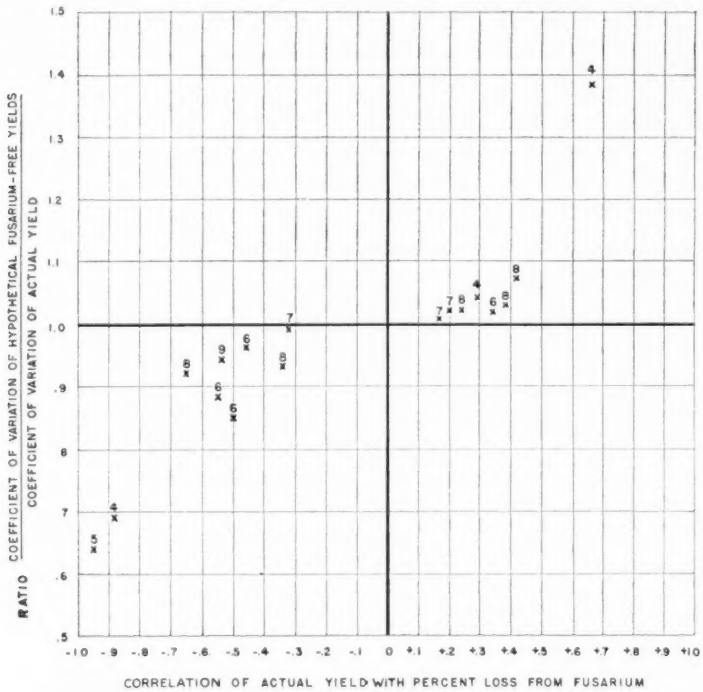

RATIO COEFFICIENT OF VARIATION OF HYPOTHETICAL FUSARIUM-FREE YIELDS / COEFFICIENT OF VARIATION OF ACTUAL YIELD
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
-.10 -.9 -.8 -.7 -.6 -.5 -.4 -.3 -.2 -.1 0 +.1 +.2 +.3 +.4 +.5 +.6 +.7 +.8 +.9 +10
CORRELATION OF ACTUAL YIELD WITH PERCENT LOSS FROM FUSARIUM

FIG. 2. Potato Fusarium data by individual States, illustrating the fact that the effect of a disease on yield variation depends on the correlation between loss and yield. The figure above each point shows the number of years for which data were available for the State concerned. The curvilinear relation is mainly due to the cramping of the correlation coefficients near the ends of the scale; the use of Fisher's z transformations in place of the correlation coefficients themselves would have shown a more nearly rectilinear relation.

was negative, the data indicate that the variation of Fusarium-free yields would have been less than that of the actual reported yields, while for each of the 8 States in which the correlation was positive, Fusarium-free yields would have been more variable. Were Fisher's z values used in place of the correlation coefficients, the relation would more nearly approach a straight line. Correlation of the loss with the disease-free yields in place of the actual would have resulted in moving the plotted points varying distances toward the right.

Even with a disease correlated positively with disease-free yield, like potato blight, the effect of the disease would be to increase yield variation if the loss variation were large enough. Figure 1 was based on average losses that occurred in fields most of which were sprayed. If regional figures were available for unsprayed fields the findings might be quite different. Before present control procedure was developed and with the varieties that were in use a century ago, the effect of late blight on national yields was anything but stabilizing. One has only to remember its part in causing the historic Irish famine (10) with its resultant loss of many thousands of lives and wholesale emigration to the United States. To put the case in another way, the progress that has been made in the control of the late blight has changed it from a catastrophic thing that upset all expectations, into one that no longer seriously affects the dependability of total regional yields so long as the rather expensive spraying schedules are followed. Not even the most extreme detractor of agricultural progress would be willing to return to potato-raising on the basis of 1845.

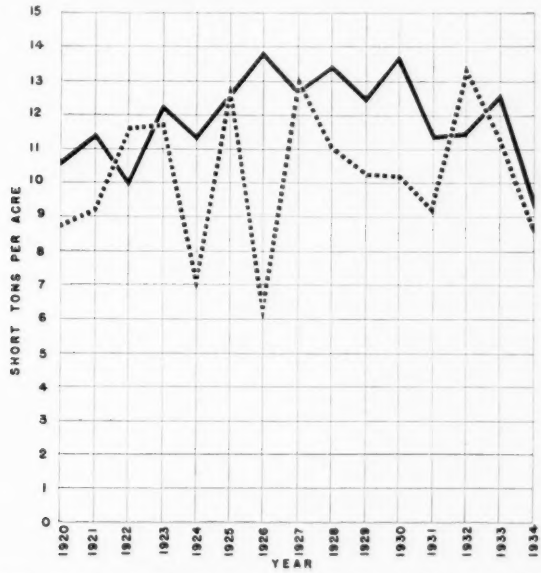


FIG. 3. Sugar-beet yields in Idaho and Colorado. Solid line, Colorado where 90 per cent of crop is grown outside the curly-top areas. Broken line, Idaho where curly top is prevalent.

Curly top of sugar beets furnishes a striking modern case of crop variation due to disease, irrespective of correlation. The effect can be examined by comparing yield dependability in Idaho and California where the disease is prevalent, against that in Colorado where about 90 per cent of the crop is grown outside the curly-top areas. Figure 3 shows the tremendous changes

in the reported Idaho production in the bad curly-top years as compared with the relative constancy of those for Colorado. For the entire 15-year series of yields[3] the coefficient of variation was 21 per cent in Idaho and only 11 per cent in Colorado. In the King City district in California, Carsner's figures (2) show yields to be even more erratic than those in Idaho as a result of the same disease. When the absolute variation in loss is so large, it must destroy the dependability of yield, no matter what the correlations may be. The curly-top-resistant varieties now coming into general use should result in much more stable yields in this crop. Recently, Brandes and Coons (1) called attention to the facts that yield fluctuations in certain States are definitely assignable to curly top and that sporadic low yields in certain other States are due to Cercospora leaf spot.

The foregoing discussion has been directed mainly to regional yields. Table 2 gives some similar data for national yields. Production totals for a crop grown generally over an area as large as the United States are, of course, less affected by disease fluctuations than are regional yields, because all parts of the area are not likely to suffer heavy losses in the same year. But for crops that, because of weight, bulk, or perishability, cannot be shipped economically from region to region, the effects of a regional epidemic can be nearly as serious to the consumers of that region as would a world shortage. On the other hand, such an epidemic in a crop that can be shipped long distances is more harmful to the producer than a world-wide epidemic, because he suffers reduction of output without profiting from a corresponding increase of price, as brought out in the enlightening discussion by Smith and associates (7). Regional effects of disease on variation are, therefore, in some respects more important than national. For certain crops the national production is so restricted in area that regional loss is national in effect; such a situation is analyzed by Stevens[4] for cranberry.

The ordinary measures of average variation have their greatest utility in connection with values that are determined by numerous factors of approximately equal importance and which, therefore, fall into approximately normal distributions. There are certain disease effects that depart too far from the ordinary to be adequately expressed by the usual variabilty measures. In view of the sudden geometric increases that sometimes occur in populations of insects, such occasional extreme results are perhaps more likely with a disease like curly top of sugar beets, in which the insect vector is the main controlling factor, than with diseases that are dependent on several factors of the same general order of magnitude. The single factor most likely to produce a completely unpredictable event in the phytopathological

[3] Yields taken from U. S. Department Agriculture Yearbooks 1924 to 1935.

[4] Stevens, N. E. An attempted analysis of the economic effects of cranberry diseases. U. S. Dept. Agr. Plant Disease Reptr. **19**: 112–128. 1935. [Mimeographed.]

field is the movement of a pathogen from one region or continent to another in which there is a hyper-susceptible host. Such cases are too well-known to require cataloguing.

VARIABILITY OF A CROP AS AFFECTED BY MORE THAN ONE DISEASE

The combined effect on yield variability of two or more diseases that attack a crop evidently depends not only on the amount of variation in the losses and their correlation with yield, but also on the extent to which the diseases are correlated with each other. If one of 2 diseases is favored by cold weather and the other by hot, the losses they cause are likely to be negatively correlated with each other, and their combined effect on the variability of the annual yield figures less than that of either alone. Tip burn and late blight appear to be negatively correlated with each other; for the 4 States for which data were available for the 10 years studied, the correlations between percentage of tipburn and percentage of late blight of potatoes were -0.25, -0.32, -0.48, and -0.62. On the other hand, if a crop be attacked by two diseases that are favored by the same conditions, as is reported by Folsom (5) for potato late blight and botrytis blight, the combined effect of the two diseases on yield variation must be greater than the effect of either alone. Another example of additive variability from two diseases is provided by scab and stem rust of wheat. In 10 series of comparisons, in the last decade in Minnesota and North Dakota, of the annual yields[5] of susceptible wheat varieties with varieties classified merely as resistant to stem rust, the mean coefficients of variation were approximately equal, the variation of the yield of the susceptible varieties being only 1.04 times that of the resistant ones. On the other hand, tests in three localities in Iowa[6] showed Progress wheat, resistant to scab as well as to rust, yielding more and being less variable from year to year than the susceptible Marquis. At one place over a 6-year period and at another over a 5-year period, the coefficients of variation for Marquis were 1.5 times as great as those for Progress; and at the third place over a 3-year period the coefficient was 1.2 times as great. The accumulation of such comparative data through a longer period would be highly desirable.

Another illustration of the effect of a combination of diseases on the yield variability is found in unpublished data on sugar-cane furnished by R. D. Rands. The coefficient of variation for annual total yields of this crop in Louisiana increased from 16 per cent during an 18-year period centering

[5] Data supplied by S. C. Salmon, Division of Cereal Crops and Diseases, Bureau of Plant Industry.

[6] Burnett, L. C. Small grains. Information from experiments in progress. Iowa Agr. Expt. Sta. Farm Crops and Soils Sect., Farm Crops Sub-sect. Leaflet FC, 2. 1932; 4. 1933; 6. 1934. [Mimeographed.]

in the 90's to 28 per cent in a period of similar length after the invasion of 3 new diseases, a change that he believes to be mainly due to these diseases.

The apparent effects of more than one disease on the variability of yields are given in table 2. It is worth noting that the diseases of oats apparently increase variability of national yields to an extent quite out of proportion to the reduction in average yield.

TABLE 2.—*Variability in estimated yields per acre of various crops in the United States from 1920–1929*

Crop	Disease	Reported yield		Computed disease-free yield	
		Average	Coefficient of variation	Average	Coefficient of variation
Cotton	Fusarium wilt	162 lbs.	12.0	167 lbs.	11.4
Cotton	All	162 lbs.	12.0	190 lbs.	11.7
Oats	All	29.8 bu.	11.9	32.3 bu.	10.5
Potatoes	All	111 bu.	8.5	141 bu.	9.9
Potatoes	Late blight	111 bu.	8.5	117 bu.	10.9

DISEASE UNCERTAINTIES AFFECTING THE INDIVIDUAL PRODUCER

The variations caused by diseases in the returns to the individual farmer are on the whole more serious from the standpoint of social security than the national or regional yield variations. Farming continues an individual venture, crowded with risks too large for the individual to carry readily. The effect of disease in decreasing crop predictability is much greater for the individual holding or for a local community than for the State or national yields already considered. A disease that has relatively little effect on yield totals may be periodically disastrous to single farms. This has been the case, for example, in recent years with cotton wilt, which appears (Table 2) to have little effect on national yield variation. Every experienced pathologist has seen so many extreme local losses to farmers that there is no need for citing examples to the readers of this journal. The growers of tree crops are subject to perhaps even greater uncertainty than the ordinary farmers, because of the long period of cumulative risk to which they are subject.

There is little quantitative information bearing on the effect of disease variability on individual or local yields. Some indication as to the influence of diseases on local variation can be secured from the results of disease-control experiments. This approach is not without difficulties. In interpretation it must be kept in mind that a treatment sometimes has other effects than disease control; and that if it be uncertain in its action, it may itself become an additional factor affecting variability. In the same way, a resis-

tant variety may increase variation unless it is dependable in other respects, as well as in resistance to the disease in question.

A treatment may, of course, be profitable without decreasing variability. Records of potato spraying in Pennsylvania are available for 1918–1930 that, according to Denniston and Hodgkiss (3), "show that spraying, when properly done, has been as equally profitable in non-blight years as in years when blight was present". The coefficient of variation computed from their data on yields in the sprayed fields was greater by one fifth than that for the unsprayed fields.

Examples of treatments that decreased variation are furnished by the writers' data on damping-off control in coniferous seedlings. At the Bessey Nursery of the U. S. Forest Service the sulphuric-acid soil treatment was applied to sowings of jack pine made at 12 different times during a period of several years. The coefficient of variation for yields per unit quantity of seed during the entire period was 74 per cent in the nontreated plots and 34 per cent in the treated. At the Fort Bayard Nursery the variation of 6 nontreated plots of ponderosa pine was 30 per cent and that of the 12 acid-treated 17 per cent. At the Monument Nursery the variation of 8 simultaneously sown nontreated plots of Engelmann spruce was 17 per cent and that of 10 aluminum sulphate-treated ones was only 7 per cent; for 11 simultaneously sown pairs of plots of Douglas fir at the same nursery the variation of the nontreated plots was 32 per cent and of those treated with aluminum sulphate 5 per cent. These are not specially selected cases; they represent the available experiments in this field in which replications were sufficiently numerous for variability analysis. Variation in yield of sowings at different times makes it difficult for the forest nurseryman to gauge his sowing operations to the needs of the field planting program. Variation of yields, either of different sowings or in different beds of the same sowing, hampers control of stand density and thus of quality of stock.

Variation due to disease in individual holdings can make trouble in the marketing as well as in the growing process. The uncertainties introduced into the distribution of fruits and vegetables by the fungi that attack them are too well known to require comment. A type of uncertainty less generally known, is that introduced into the purchase and utilization of timber lands by the variation in the amount of hidden decay already in the trunks. The best available quantitative data[7] are for Douglas fir, our largest single source of saw timber. Gross or apparent yield represents the yield that would have been obtained had there been no decay. For 23 plots below the age of 350 years, in different parts of the optimum range of this species and all on sites

[7] Data taken from tables 1 and 3 and figures 3 and 9 of U. S. Dept. Agr. Technical Bulletin 286 entitled "Decay and other losses in Douglas fir in western Oregon and Washington" by J. S. Boyce.

classified as of second quality, the expected gross yields per acre were obtained from curves of volume over age prepared by the original investigator. For each plot the difference was then determined between the actual gross yield and the expected, and expressed as a percentage of the expected value. These deviations from expectation averaged 20.2 per cent. The deviations of the yields of undecayed wood from the expected undecayed yields for those ages, obtained in the same way, were found to average 26.7 per cent. The root-mean-squares of the deviations, which are roughly equivalent to coefficients of variation around a moving average, are 23 per cent for the gross and 32 per cent for the net yields. In other words, the variation from the expected yield of sound wood has been much increased by the decay. In practice a prospective purchaser of timberland usually buys on the basis of an actual cruise of the area concerned, which gives him a more reliable expectation value for gross yield than does the generalized curve over age; and since the accuracy of cruising in estimating sound volumes is much less than in estimating gross volumes, the part played by decay in causing actual yields to depart from estimate is in fact probably greater in proportion than is indicated by the figures given. Unfortunately, cruise estimates for the study plots are not available. The pathologist has made a real contribution to industry in this case, by developing criteria by which hidden decay can be better estimated and the cruise estimates of sound timber can be made more reliable; this does not necessarily decrease the variation itself, but attains much the same end in that it decreases the variation from estimate which has proven one of the difficulties in the utilization of the timber of the Pacific Northwest.

CONCLUSIONS

Diseases in general may be expected to increase variation in production. The larger the variation of the disease losses or the more the disease losses tend to occur at times when other injurious factors also are active, the greater is the increase they produce in the variation of yields. Some diseases, however, are most serious in years otherwise favorable to the crop. Such diseases, if the loss variation is not too large, actually may decrease the variation in annual yields of a region as a whole. Late blight of potatoes appears to have become such a case—once a prime source of uncertainty, causing one of the great famines of history, and still a source of expense and worry to the individual farmer, it has been reduced to an apparently stabilizing factor, so far as regional and national yields are concerned, and so long as the recommended spraying schedules are maintained.

Stabilizing the yields of the individual grower is more essential from the standpoint of the producer than stabilizing regional yields. Disease losses to local communities or individual growers are more variable than regional

losses and diseases are, therefore, more likely to increase the variability of local yields than of regional yields.

In the choice of problems for investigative emphasis, it is suggested that when other considerations are equal, those diseases are particularly in need of attention, from the standpoint of both producer and consumer, in which variation is large or is negatively correlated with annual yields, so that better control will reduce yield variation.

DIVISION OF FOREST PATHOLOGY,
BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE,
WASHINGTON, D. C.

LITERATURE CITED

1. BRANDES, E. W., and G. H. COONS. Beet crop problems: Science helps find the answers. Facts About Sugar **29**: 83–85, 117–121. 1934.
2. CARSNER, E. Curly-top resistance in sugar beets and tests of the resistant variety U. S. No. 1. U. S. Dept. Agr. Tech. Bull. 360. 1933.
3. DENNISTON, L. T., and H. E. HODGKISS. Profitable potato spraying. Pennsylvania Agr. Expt. Sta. Cir. 137. 1931.
4. FARIS, J. A., V. F. TAPKE, and H. A. RODENHISER. Wheat smuts and their control. U. S. Dept. Agr. Farmers' Bull. 1711. 1933.
5. FOLSOM, D. *Botrytis cinerea* as a cause of potato tuber rot. Phytopath. **23**: 993–999. 1933.
6. NEAL, D. C., and W. W. GILBERT. Cotton diseases and methods of control. U. S. Dept. Agr. Farmers' Bull. 1745. 1935.
7. SMITH, H. S. and others. The efficacy and economic effects of plant quarantines in California. California Agr. Expt. Sta. Bull. 553. 1933.
8. STEVENS, N. E. Plant-disease hazards, though very fluctuating, demand constant action. U. S. Dept. Agr. Yearbook **1931**: 294–297. 1932.
9. ———. Some significant estimates of losses from plant diseases in the United States. Phytopath. **23**: 975–984. 1933.
10. ———. The dark ages in plant pathology in America: 1830–1870. Jour. Wash. Acad. Sci. **23**: 435–446. 1933.
11. ———, and J. I. WOOD. Losses from corn ear rots in the United States. Phytopath. **25**: 281–283. 1935.

CLADOSPORIUM LEAF BLOTCH OF PEONY

LLOYD J. MEULI[1]

(Accepted for publication July 12, 1936)

Because of an increasing severity of peony leaf blotch in several Wisconsin nurseries, a comprehensive study of the disease and its control was begun in the fall of 1932. The vigor of infected plants was not noticeably diminished, but foliage discoloration of such plants frequently detracted from the appearance and value of the marketable product. The causal organism was described briefly and named *Cladosporium paeoniae* by Passerini in 1876 (5, 7). The disease has received little attention in this country during the past 2 decades other than brief reports and general descriptions[2] (1, 2, pp. 244–246), although it probably was an unimportant malady in the United States for some years prior to these reports.

Cladosporium leaf blotch has been reported from 19 States in this country as well as from the District of Columbia, Alaska, Canada, and numerous foreign countries. Of its occurrence in Europe, Whetzel (8) states, " . . . leaf blotch . . . is to be observed in almost every peony planting today. . . ." These reports relate primarily to commercial plantings of peonies where the cumulative effects of the disease have become so important as to destroy the ornamental value of the foliage desired in late summer and autumn.

DESCRIPTION OF THE DISEASE

Leaf blotch of peony is encountered only on aerial portions of numerous peony varieties, although leaf symptoms are the most conspicuous. Initial infection becomes manifest on the ventral surface of the leaf as small, circular or oval discolored areas, usually $\frac{1}{2}$–1 mm. in diameter. Infection spots spread slowly and reach a diameter of 2 to 3 mm. before they penetrate through the thickness of the leaf. They may be present in greater or lesser numbers (Fig. 1, A) per leaf, depending on severity of infection; and, as their growth continues, they may merge, giving the leaf an irregular, blotchy appearance. The extent of the infection is easily recognized by the slow advance of the dull, chestnut brown of the lower surface and the glossy, dark purple of the upper surface. This discoloration remains throughout the season as typical of the disease, and is not to be confused with a natural change in leaf pigmentation sometimes occurring toward the end of the grow-

[1] The writer is indebted to Dr. L. R. Jones, Professor of Plant Pathology, University of Wisconsin, who suggested this research and gave generously of his valuable advice and assistance throughout the investigation.

[2] New Jersey Agr. Expt. Sta. Dept. Plant Path. Diseases of peony. (**I** + **S** Nursery disease notes **1**(6)). 1928. [Mimeographed.]

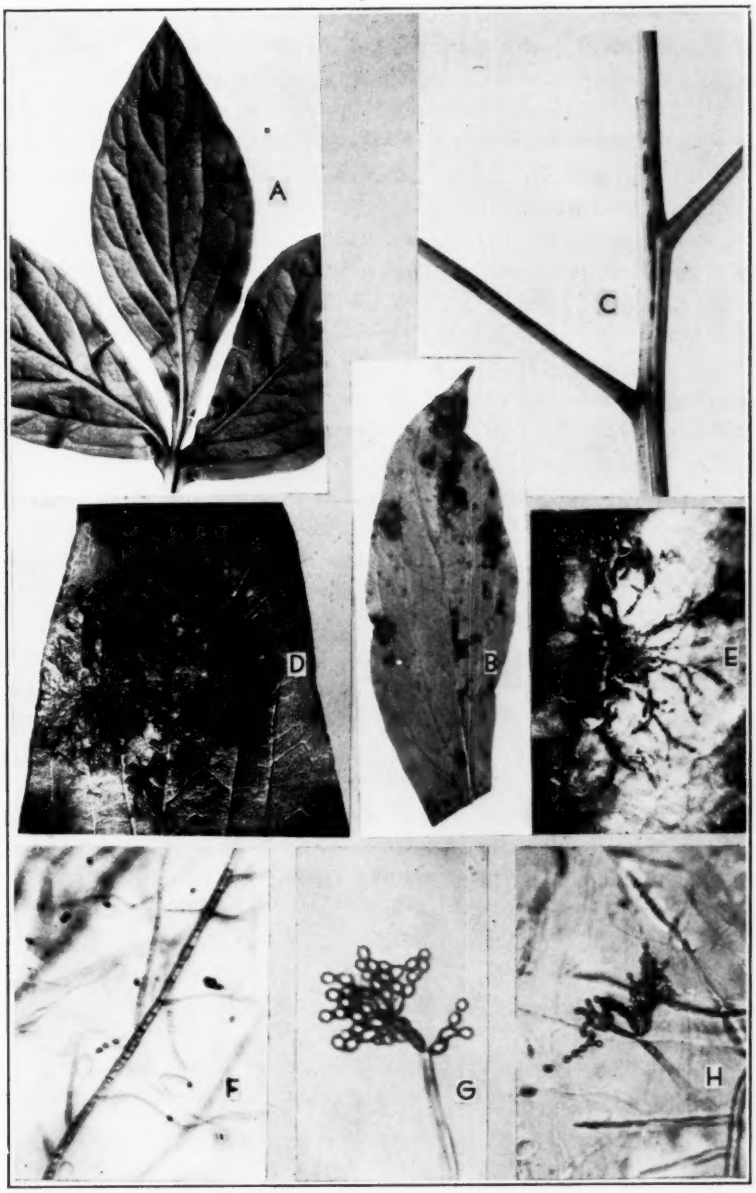


FIG. 1. *Cladosporium paconiae* on peony foliage and in pure culture. A. Natural infection on the upper leaf surface. B. Dendriform growth of natural infection on the lower leaf surface when floated on 10 per cent sugar solution. C. Elongated lesions from natural stem infection. D–E. Artificial infection on excised leaflets. D. Slightly enlarged. E × 7. F. Submerged mycelium and spores in potato-dextrose agar. Rounded cell contents atypical. × 176. G–H. Mature sporophores and conidia on potato-dextrose agar. G × 400; H × 240.

ing season. Unless abnormal drought conditions prevail, which may result in the collapse of the cells, the infected leaves retain their succulence and vigor throughout the season. Marginal infection predominates, especially near the leaf tip, and slight distortion may occur as growth continues. Outer leaves of the plant are ordinarily attacked first. The bushy nature of the host acts as a protection to the inner foliage against inoculum carried in spattering rain and wind.

Weiss[3] reports blossom infection, which he attributes to *Cladosporium paeoniae,* and Martin (3) reports the fungus on abortive buds. No infection of this type, however, has been observed in this region. The early blossoming period and short duration of the blooms appear to provide an escape from the slow-growing fungus, although simple leaves and leaf-like bracts located near the seed pods become severely infected, as well as the seed pods themselves. Petiole infection is relatively unimportant and is similar in appearance to stem infection.

On the young green stems, infection is first apparent as elongated, reddish brown streaks (Fig. 1, C) with slightly diffuse margins. The lesions present a plane surface, but, as growth continues, those near the crown of the plant are inclined to coalesce, darken, and become somewhat depressed. Lesions on the upper stems are similar in shape and color but are fewer in number. They tend to retain their individuality and become slightly raised rather than pitted. Infection spots are abundant at branch and petiole bases where débris of old infected parts and fallen petals may lodge and become a source of infection or provide favorable environment for the establishment of the fungus.

Any form of sporulation is conspicuously absent during the growing season, and only under favorable environmental conditions is the smooth surface of the leaf broken by masses of dark green conidia.

Pathological Histology.—In the early stages of leaf infection the slender hyphae of the fungus are found growing on the surface or partly or totally imbedded in the cuticle (Fig. 1, D–E). As the fungus develops, its surface ramifications become more abundant, but only seldom does a hypha penetrate a stomatal opening. Fresh material viewed in low magnification clearly showed the radiating hyphae in contact with discolored epidermal cells and leaf hairs, the pigmentation occurring several cells on either side of the superficial mycelium. This typical brown and purple discoloration always disappeared in prepared paraffin and cleared sections. Even those cells in close proximity to the mycelial threads appeared normal and healthy. No visible means of sustenance for the fungus were observed nor were any hyphae seen below the epidermal layers of the apparently healthy tissue. Slides of dead, infected leaf material collected in the field revealed abundant

[3] Weiss, F. Notes on some diseases of ornamentals. U. S. Dept. Agr. Bur. Plant Indus. Plant disease Reptr. **16**: 122–124. 1932. [Mimeographed.]

mycelium throughout the tissues and what appeared to be conidiophore stalks protruding through the stomata. There is the possibility that such conditions were due to secondary organisms or saphrophytes. *Cladosporium herbarum* was frequently isolated from collected material, and its appearance might easily be confused with that of the true pathogen. There is also the possibility that *C. paeoniae* is only slightly parasitic and can attack the inner tissues only after their death. Opportunity did not permit a more thorough investigation of this phase of study.

Taxonomy.—Passerini at Parma City, and Gorizia, Italy, first described the peony leaf-blotch fungus, naming it *Cladosporium paeoniae*. His very brief description of the fungus as found on *Paeonia edulis* was published in *Just's Jahresbericht* in 1876 (5). Saccardo (7, p. 362), besides publishing this description, but naming the host *P. officinale*, also gives Passerini credit for having discovered a variety of this organism, named *C. paeoniae anomale*, on leaves of *P. anomala* in the subalpine forests of Siberia. The existence of this new variety evidently is based on its occurrence on a different species of peony, but the two fungi probably are identical. No true identifying characters were given in these descriptions that might differentiate *C. paeoniae* from other Cladosporium species beyond the fact that it was pathogenic on peonies. Some difficulty was experienced in identifying the parasite because of this, for the study was begun late in the fall when natural foliage was no longer available, and it was only after forced peony foliage had been secured in midwinter that the authenticity of the fungus could be established by means of infection trials in the laboratory.

Only the conidial stage is known, which places it in the *Fungi Imperfecti* in the order Moniliales (Hyphales). Infected material, permitted to overwinter on the ground in net bags, was examined, without success, for spore forms other than conidia. Small masses of mycelium have been observed rounded up in very old agar tube cultures, but it is questionable as to whether or not these are abortive attempts to form sclerotia or ascigerous fruits. Numerous transfers were made of this type of mycelium in an effort to force these bodies to maturity, but without success.

Morphology.—In culture a great deal of variation may be observed in mycelial growth. Young, thin-wall hyhpae usually are branched and composed of long, hyaline cells. With further development, the cell diameters increase and the walls become thickened and darker (Fig. 1, F). Typical chlamydospore formation has been observed in which excessively thick walls give the cells a rounded appearance.

In nature the conidiophores occur in erect, compact tufts and are usually of greater length than those observed in culture (Fig. 1, G–H). The frequently branched, septate stalks may vary somewhat with conditions, but, normally, their dimensions are similar to the hyphae from which they arise. Each sporophore may bear several branched or branchless chains of acrog-

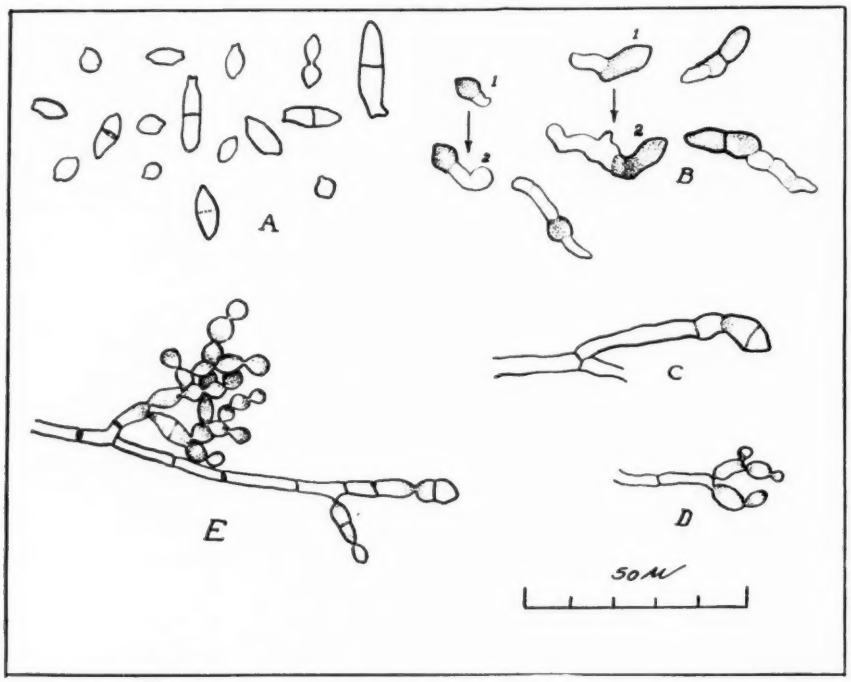


FIG. 2. *Cladosporium paeoniae* on malt agar. A. Variations in size and shape of conidia. B. Germination of conidia (1) at the end of 24 hours and (2) at the end of 48 hours. C.–D. Development of young sporophores. E. Mature sporophore.

enously formed conidia. The majority of the spores (Fig. 2, A) are small, round or lemon-shape and constitute the greater part of the branching chains. The larger ellipsoid spores may be either continuous or one-septate. These conidia are relatively few in number and represent the basal spores to which one or more small chains are attached. The place of attachment of detached spores is often marked by small geniculations at the ends of the conidia. Measurements of spores from malt agar tube cultures averaged 6.4 by 3.7 μ for the small, round conidia, 11.9 by 4.0 μ for the continuous ellipsoid conidia, and 16.5 by 5.4 μ for the larger septate ellipsoid spores.

Cultural Studies.—First attempts to isolate the causal organism by the poured-plate method were hampered by the close association of numerous, fast-growing fungi. The slow-growing *Cladosporium paeoniae* could not compete with the faster growing secondary species of Septoria, Penicillium, Rhizopus, and a saprophytic *C. herbarum* that were often present. The true pathogen was easily isolated when it was discovered that successful sporulation could be obtained by placing dried infected material and 1-year-old pressed specimens in moist chambers for 5 days.

Single-spore cultures from all types of conidia from various plant parts

showed no marked differences in artificial culture. All cultural work herein reported is based upon single-spore cultures of the fungus.

The organism germinated and grew well on several liquid and solid media. Colonies growing on malt-agar plates increased their radial growth by an average of 2.4 millimeters per day at the optimum temperature. The color of young transfers for the first 3 days is Lincoln green (6). The color gradually changes and by the 18th day becomes an olive brown shade. The surface mycelium forms a fluffy covering over the agar with an abundance of conidiophores and conidia. Submerged mycelium appears beneath the surface of the agar at a point below the oldest portion of the culture in 10 days. The agar subsequently becomes thoroughly ramified by the subsurface development. *Cladosporium paeoniae* on malt-agar slants, sealed with lead foil, were kept alive and viable more than a year. At this age they had lost their pathogenicity.

Excellent germination was obtained in yeast-infusion glucose and 10 per cent peony decoction. Germination was slightly reduced in tap water and only about 15 per cent germination occurred in distilled water. Early stages of germination have been observed within 6 to 8 hours among all forms of conidia, while the majority of spores germinate in about 12 hours. It is not uncommon for 2 germ tubes to be borne from the ends of a single spore. In distilled water and peony leaf decoction, abnormal germination often occurred (Fig. 3, C, G, E) in which sporophores were formed directly from the spores soon after germination. On agar, germination was slightly slower than in liquid media, but growth appeared to be more normal. The vigor of the young germ tube during the first 20 hours appeared to be proportionate to the size of the spore or cell from which it emerged (Fig. 2, B).

Pathogenicity.—Time did not permit pathogenicity tests to be made in the field. Controlled tests, however, were made on forced peony foliage in the greenhouse and with excised leaves in the laboratory.

Healthy peony roots, dug in late fall, were subjected to a temperature several degrees below freezing from 18 hours to 12 days and "heeled in" the root cellar until needed. When potted, these plants produced normal, healthy young leaves in approximately $1\frac{1}{2}$ months, and a few weeks later several plants were in full bloom. Many of the buds were abortive, and in some cases the buds were removed to stimulate more vigorous foliage growth.

Plants sprayed with a mono-conidial suspension developed leaf lesions in 16 days and elongated stem lesions were observed several days later. The spread of the organism was slow and dendriform (Fig. 1, D–E) similar to the type of growth produced on naturally infected plants when placed in a moist chamber (Fig. 1, B). Corresponding tests of pathogenicity, using the same methods of inoculation, were made on excised leaves floating on a 10 per cent sugar solution in Petri dishes (9). Leaves from various portions of the plants, both upper and lower surfaces, showed macroscopic lesions in 9 days. Subsequent growth was typically dendritic (Fig. 1, D–E). The

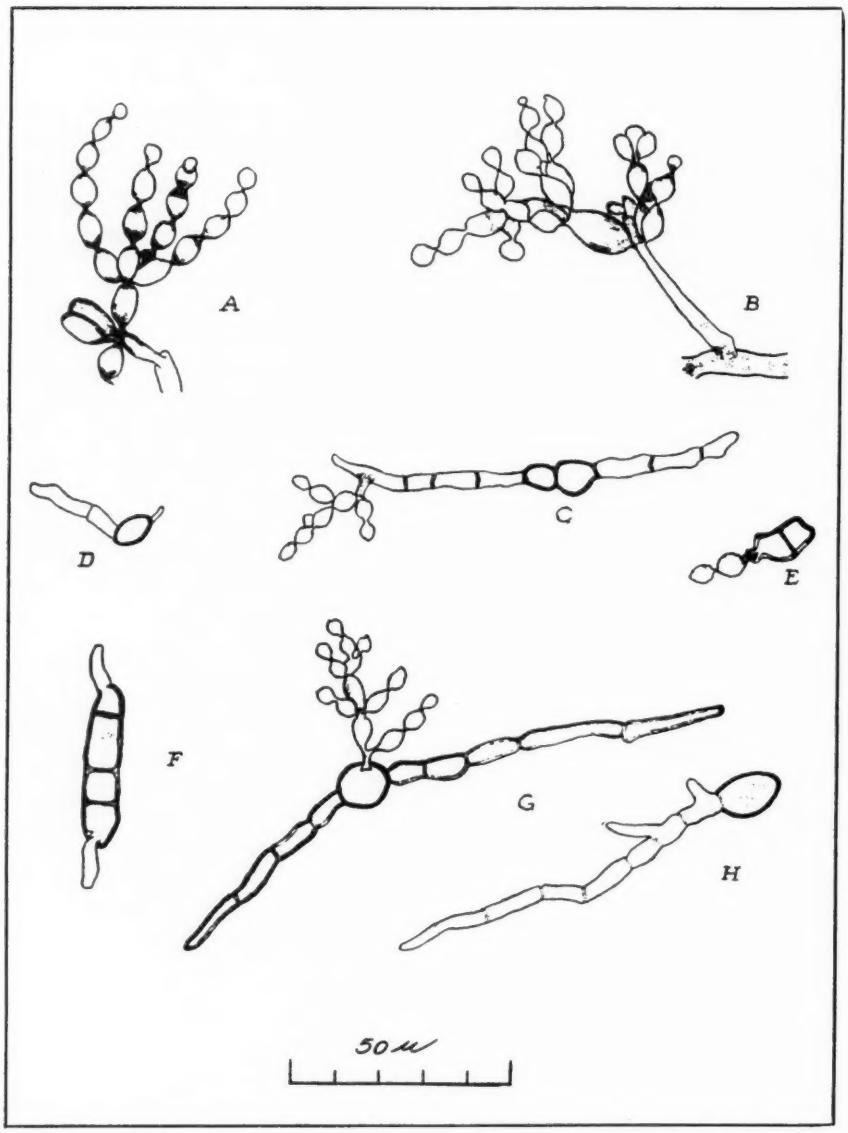


FIG. 3. *Cladosporium paeoniae* from hanging drop cultures, age 30 days. A–B. Mature sporophores showing typical chain formation of the conidia. Conidia in A from a single large basal spore. Yeast infusion glucose. C–G. C and E and G. Abnormal sporulation of germinating spores. C and G. In peony leaf decoction. E. In distilled water. D and H. Normal germinating spores in yeast-infusion glucose. F. Abnormally large, several-septate spore in the process of germination in yeast-infusion glucose.

reisolated organism, which was constantly associated with the foliage lesions, compared exactly with the microscopic and cultural characters of the original *Cladosporium paeoniae* inoculum. Reinoculation always resulted in the disease.

Seasonal Development of the Disease.—The first leaf infection of the season became evident shortly prior to the time of blossoming, or about June 1. The advance of the fungus throughout the season was slow, and from 5 to 90 per cent of the leaf area became discolored. Twig and petiole infection usually appeared several days later than leaf infection and was much slower in its advance. In many cases of slight infection stem lesions were absent or very inconspicuous; with more severe infection the number of stem lesions increased proportionately. Stem infection in no way appeared to effect the vitality or strength of the plants even though the stems were completely girdled with lesions as the season progressed.

Under natural conditions conidia were formed only in the presence of favorable moisture conditions provided by the late fall and spring rains. When such conditions were duplicated in moist chambers, successful sporulation was secured from dead, infected material. Tests were made in an attempt to force sporulation of living infected tissue by means of high relative humidity of the surrounding air. When these tests were made in July, there were no signs of sporulation in the field. The cut ends of similar, typically infected stems were sealed in flasks containing a 10 per cent sugar solution. The stems were then placed under 3 bell-jars, each jar being subjected to a different relative humidity. These controlled conditions were obtained by bubbling saturated air through solutions capable of reducing the atmospheric moisture to 50, 70, and 90 per cent relative humidity (4, p. 67–68). These figures may have been slightly higher due to the fact that transpiration water was not entirely expelled from the bell jars. Abundant sporulation was observed in 6 days on leaf lesions exposed to 70 and 90 per cent relative humidity. At the end of 9 days only very slight sporulation was observed on leaves in the 50 per cent chamber. A series of control stems exposed to the natural prevailing humidity showed no conidial formation. This experiment was repeated using tap water in place of the sugar solution with the same results.

Sporulation may be observed occasionally in late fall during precipitation periods. Tests were made to determine whether or not these spores could overwinter in the ground. Surface soil was collected near infected plants in the early spring, mixed with water, and the supernatant liquid used as inoculum. Microscopic examination of this solution revealed an occasional Cladosporium-like spore, but healthy peony plants used as a differentiating host remained noninfected when sprayed with the solution. That the mycelium overwinters in a dormant stage has been confirmed by masses of dark green conidia produced from overwintered material and even from pressed specimens over a year old. It is apparent that primary infection

originates from this overwintered material. No secondary infection occurs in this region, for no sporulation takes place on the current year's lesions during the growing season.

Observations in the field and laboratory indicated that condidia were disseminated primarily by meteoric water. It was apparent from examination of slides that condidia became detached promptly when in contact with water. Complete sporophores with attached chains could be examined only as they grew in hanging drops or on thin agar plates. Sporulating tissue could be shaken quite sharply in a dry atmosphere without detaching the spores. Attracted by the sticky sweet exudate on the buds, ants are frequently observed associated with the host at the time of infection. One may surmise that spores could be easily carried on and indirectly disseminated from the sticky appendages of these insects. Infection was noticeably severe on those portions of the plant most frequently traversed by the ants: namely, the bud bracts and surrounding single leaves. Some infection may be attributed to sucking insects, for small projecting tips, suspiciously similar to insect wounds, have been observed centrally located in very young lesions.

Control Measures.—Investigation of leaf-blotch control was undertaken at Turville's Nursery, Madison, Wisconsin, where an extensive planting of approximately 6 acres of severely infected peonies was made available for the study. The disease was present only on the broad-leaf, herbaceous varieties. The slender-leaf *P. tenuifolia* remained completely resistant in the midst of severe infection. This is of little consequence, for shortly after its early blooming period the entire plant normally dies down until the following spring.

There is a wide range of susceptibility among the broad-leaf varieties. Among several commercial plantings in which leaf blotch was prevalent, the most susceptible varieties were Oshkosh White, Felix Crousse, and Livingstone. Less infection appeared on Augustin d'Hour and Mathilde de Roseneck, still less on Louis Van Houtte, Edulis Superba, and Jules Calot, while Gigantea and Humei Carnea seemed quite resistant. As time is a significant factor in peony breeding and blooms of commercial value must be secured, breeding for resistance to leaf blotch becomes impracticable, especially when the disease may be controlled by other measures.

Sanitation.—In early autumn badly infected foliage was removed from 10 centrally located rows of plants. These were flanked on either side by plants whose foliage was allowed to remain as controls throughout the following growing season. Cut stems were placed in small piles throughout the field and burned. Additional sanitation involved burning thick layers of marsh hay on 2 plots 40 square feet in area and separated from each other by an unburned control strip. It was believed that such treatment would reduce still more the overwintering of infested material.

Observations the following summer indicated that uncut, unburned, flanking rows suffered more leaf blotch than the portion that had been sub-

jected to sanitation. The additional burning of marsh hay had further eliminated some of the disease. These results were determined by a comparison of susceptible varieties found in the different treated areas. It was concluded that burning tops in the autumn was a useful and commendable practice that would probably give excellent control if carried out from year to year. Excessive burning, however, by means of straw or hay does not produce a sufficiently greater increase in control over ordinary sanitation to warrant the expense.

Sprays.—Three different sprays were applied to infested areas chosen at random over the field, leaving suitable control strips between the treated plots. Two lime-sulphur sprays were applied to the soil, one in the late fall and the other in early spring. In late spring the third application of a 3–2–50 and a 1½–1–50 Bordeaux mixture was distributed evenly over clean, young plants on adjacent plots. All sprays were applied at the rate of 25 liters per acre.

The soil sprays did not appear to successfully reduce leaf-blotch infection. It was unfortunate that no highly susceptible variety was present in these sprayed areas to use as index plants. Both foliage sprays reduced blotching on some of the more susceptible varieties with the stronger mixture recommended as the better of the two. There is the possibility that the fungus had already established itself at the time of spraying, for 4 days later small lesions could be detected on the leaves. An earlier spray application might prove more beneficial.

Transplanting.—Three entire peony plants, identified by the nurseryman as belonging to the variety Louis Van Houtte, were removed from the infested field. The following day these plants were placed in another field far removed from the nursery and any known source of peony leaf-blotch infection. The first plant was handled with a minimum amount of disturbance of the soil, old stems, and the current year's foliage. This restored the plant to conditions similar to those under which it previously existed. The second plant was cleaned of as much soil as could be conveniently shaken from the roots, and the old tops were removed. The third plant was washed thoroughly in tap water and the old stems removed, as would ordinarily be done in careful nursery practice.

Early summer of the following year revealed easily visible spots on the first plant, although they were fewer and less advanced than those in the original, infested area. The plant from which the soil had been shaken had very little leaf spotting and only an occasional stem and petiole infection. The plant whose roots had been washed was nearly free of the disease. These observations were substantiated by another examination in the fall.

Parallel experiments in which the peony roots were treated with various concentrations of formaldehyde, Semesan, and Corona produced results comparable to those secured when the roots were washed in water.

It was concluded that transplanting, even with old débris present, re-

duces foliage infection, while the differences between washed and unwashed roots were so slight as to be considered insignificant; both practices are to be highly recommended in reducing the amount of infection. It seems likely that the disease might easily be controlled by moving an infested planting to another portion of the nursery and by taking precaution to remove the soil and infected tops as would ordinarily be done before marketing the stock. The feasibility of such a step has been observed in a consignment of approximately 50 plants acquired from the infested area by an adjoining park. The following spring new foliage remained disease-free, although the nursery was only 300 yards distant. The short range of the disease is noticeable in this example, and the dependence of the fungus upon meteoric water as a means of dissemination also probably accounts for the slow yearly increase of the disease in a neglected planting.

SUMMARY

A detailed description of peony leaf blotch, as caused by *Cladosporium paeoniae* Pass., together with some cultural, physiological, and pathological studies, are offered in an attempt to facilitate a clearer understanding of the disease.

The economic importance of peony leaf blotch is confined primarily to large peony plantings, and its effect is cumulative from year to year unless proper steps are taken to eliminate it.

Results of control experiments indicate that careful sanitation and destruction of old foliage each year or transplanting clean roots to non-infested areas or a combination of the two are recommended practices to elminate the disease.

DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

LITERATURE CITED

1. COULSON, J. G. Peony Diseases. (Abstract) Phytopath. 13: 292–293. 1923.
2. HARDING, A. (MRS. EDWARD). The book of the peony. 259 pp. J. B. Lippincot Co., Philadelphia and London. 1917.
3. MARTIN, G. H. Certain early developmental phases common to many fungi. Phytopath. 19: 1117–1123. 1929.
4. NATIONAL RESEARCH COUNCIL. International critical tables. Vol. 1. McGraw-Hill Book Co., Inc., New York. 1926.
5. PASSERINI, G. Cladosporium paeoniae. Bot. Jahresber. (L. Just) 4(1876): 235. 1878.
6. RIDGWAY, R. Color standards and color nomenclature. 43 pp., 53 col. pls. The Author. Washington, D. C. 1912.
7. SACCARDO, P. A. Sylloge fungorum. Vol. 4. Sumptibus auctoris, Patarii. 1886.
8. WHETZEL, H. H. Diseases of the peony. Mass. Hort. Soc. Trans. 1915 (1): 103–112. 1915.
9. YARWOOD, C. E. Effect of mildew and rust infection on dry weight and respiration of excised clover leaflets. Jour. Agr. Res. [U. S.] 49: 549–558. 1934.

A STUDY OF THE REACTION OF F_1 OAT HYBRIDS AND THEIR RESPECTIVE PARENTAL LINES TO INOCULATION WITH SMUTS AND RUSTS

H. B. HUMPHREY AND F. A. COFFMAN[1]

(Accepted for publication Aug. 1, 1936)

Oats are difficult to hybridize, and usually only a few crossed seeds are obtained. Investigators, therefore, have refrained from inoculating such seed with disease organisms for fear of destroying the F_1 plants after much time and labor had been expended in effecting the desired hybrids. Few, if any, reports are available of attempts to inoculate and study simultaneously the reaction of F_1 oat plants to more than one of the major diseases of oats. Several reports, however, are known that relate to studies of resistance to rusts.[2,3]

EXPERIMENTAL PROCEDURE

In the summers of 1934 and 1935, numerous oat crosses were made by the junior writer at the Aberdeen, Idaho, Substation. One or both of the parents of nearly all crosses were resistant either to stem rust (*Puccinia graminis avenae* Eriks. and Henn.) or to crown rust (*P. coronata avenae* F. and L.) or to the smuts[4,5] (*Ustilago levis* (Kell. and Sw.) Magn. and *U. avenae* (Pers.) Jens.). The F_1 seeds obtained were planted in the greenhouse at the Arlington Experiment Farm, Rosslyn, Va. Seed of crosses made in 1934 and in 1935 was sown the corresponding fall. The resistance of the F_1 plants of these crosses to the rusts and smuts of oats was studied during the corresponding winters.

In both years, the F_1 seed and the seed of their respective parental lines were sown in fertile soil in ordinary 5-inch greenhouse pots. Only 1 seed

[1] Principal Pathologist and Associate Agronomist, respectively, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

[2] Dietz, S. M. Inheritance of resistance in oats to *Puccinia graminis avenae*. Jour. Agr. Res. [U.S.] **37**: 1–23. 1928.

[3] Garber, R. J. Inheritance and yield with particular reference to rust resistance and panicle type in oats. Minnesota Agr. Expt. Sta. Tech. Bull. 7. 1922.

[4] Selections nos. 5541, 5542, 5543, 5544, and 5556 are all from the cross X S1098, Victoria × Richland; Selection 684 is from the cross X 2868, Iowa 444 × Markton; Selection 200 is from the cross X 2737, Markton × Iogold; those from 1415 are from the Red Rust-proof strain, Cliff, and C. I. 2574 and 2592 are from the crosses Markton × Idamine and Markton × Victory, respectively.

[5] Parents of crosses X A1131 are Iowa 444 × Bond, of X 34 CD, C. I. 2574 × Sel. 5543, of X 3110, Anthony × O. A. C. 144, and of X 3012, Nortex × Victoria. Selection Kans. Nos. 333638, 303644, 303636, and 303635 are selections from crosses of Markton × Fulghum, and the selections Kans. Row No. 2793 is from a cross of Richland × Fulghum, X2710.

TABLE 1.—*Reaction to artificially induced epiphytotics of smut and of stem and crown rust of F_1 oat hybrids and of plants of the parental lines of each cross, respectively. The results were obtained from greenhouse studies conducted at the Arlington Experiment Farm, Rosslyn, Va., during the winters of 1934–35 and 1935–36*

Cross No.	Varieties or selections crossed	Cross or parent	Total plants	Number plants smutted	Reaction of hybrid and parent plants to inoculation by smut and rust									
					Type of host response to stem-rust infection					Type of host response to crown-rust infection				
					0	1	2	3	4	0	1	2	3	4
		(Symbol)	(Number)		(Plants resistant)			(Plants susceptible)		(Plants resistant)			(Plants susceptible)	
(Crosses studied in 1934–1935)														
X 34 V	Iogold × Sel. 5541–101	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	5	2	...	...	5	...	...	...	...	...	...	5
		♂	7	0	1	...	6	...	...	1	...	5	1	...
X 34 C L	Sel. 200–6 × Sel. 5541–104	X	2	0	...	...	2	...	...	...	...	1	1[b]	...
		♀	6	0	1	...	3	2	...	...	...	...	5	1
		♂	11	0	...	...	10	1	...	...	...	8	3	...
X 34 C D	Sel. 684–2 × Sel. 5541–105	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	4	0	...	...	4	...	...	...	...	...	1	3
		♂	6	0	...	...	5	1	...	...	...	6	...	...
X 34 B P	Sel. 1415–8 × Sel. 5542–101	X	2	0	...	...	2	...	...	...	...	...	2	...
		♀	6	6	...	...	...	1	5	...	...	...	6	...
		♂	3	0	...	...	3	...	...	...	...	3	...	...
X 34 B Q	Sel. 5542–101 × Sel. 1415–8	X	3[a]	0	...	...	1	1	1	...	...	1	2	...
		♀	3	0	...	...	3	...	...	...	...	3	...	...
		♂	6	6	...	...	...	1	5	...	...	...	6	...
X 34 C T	Sel. 684–4 × Sel. 5542–107	X	3	0	...	...	3	...	...	...	...	3	...	...
		♀	1	0	1	...	...	...	...	...	...	...	1	...
		♂	8	0	...	...	5	2	1	...	...	8	...	...
X 34 C U	Sel. 5542–107 × Sel. 684–6	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	8	0	...	...	5	2	1	...	...	8	...	...
		♂	3	0	1	...	...	2	...	...	...	...	3	...
X 34 C W	Sel. 684–6 × Sel. 5542–107	X	2	0	...	...	1	...	1[c]	...	...	2	...	...
		♀	3	0	1	...	...	2	...	...	...	...	3	...
		♂	8	0	...	...	5	2	1	...	...	8	...	...

TABLE 1.—(*Continued*)

Cross No.	Varieties or selections crossed	Cross or parent	Total plants	Number plants smutted	Reaction of hybrid and parent plants to inoculation by smut and rust									
					Type of host response to stem-rust infection					Type of host response to crown-rust infection				
					0	1	2	3	4	0	1	2	3	4
		(Symbol)	(Number)		(Plants resistant)			(Plants susceptible)		(Plants resistant)			(Plants susceptible)	
(Crosses studied in 1934–1935)														
X 34 A M	Richland × Sel. 5543–104	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	7	7	...	...	7	...	...	...	...	...	...	7
		♂	8	0	...	...	7	1	...	...	...	8	...	...
X 34 B U	Tula × Sel. 5543–102	X	1	0	1	...	...	...	...	...	...	1	...	...
		♀	2	2	...	...	...	2	...	...	...	2	...	...
		♂	4	0	...	...	4	...	...	...	...	4	...	...
X 34 A B	Sel. 5544–102 × Markton	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	4	0	...	...	4	...	...	...	...	4	...	...
		♂	3	0	...	...	...	...	3	...	...	...	...	3
X 34 B G	Iogold × Sel. 5544–102	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	2	1	2	...	...	...	...	...	...	...	2	...
		♂	4	0	...	...	4	...	...	...	...	4	...	...
X 34 A R	Richland × Sel. 5554–103	X	2	0	...	...	2	...	...	...	...	2	...	...
		♀	4	4	4	...	...	...	...	...	...	...	4	...
		♂	1	0	1	...	...	...	...	...	1	...	...	...
X 34 A G	Sel. 5556–104 × C.I. 2574	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	9	0	7	1	1	...	...	...	9	...	...	...
		♂	1	0	...	...	...	1	...	...	...	...	1	...
X 34 A H[a]	Sel. 5556–102 × Iogold	X	3	0	1	...	1	...	1	...	1	2	...	...
		♀	8	0	8	...	...	...	...	...	3	5	...	...
		♂	8	8	8	...	...	...	...	...	...	...	8	...
X 34 A Q	Richland × Sel. 5556–102	X	1	0	1	...	...	...	...	...	1	...	...	...
		♀	2	2	2	...	...	...	...	...	...	...	2	...
		♂	8	0	8	...	...	...	...	...	3	5	...	...
X 34 B I	Sel. 5556–102 × C.I. 2592	X	2	0	2	...	...	...	...	...	2	...	...	...
		♀	8	0	8	...	...	...	...	...	3	5	...	...
		♂	2	0	...	...	...	...	2	...	...	...	2	...

TABLE 1.—(*Continued*)

Cross No.	Varieties or selections crossed	Cross or parent	Total plants	Number plants smutted	Reaction of hybrid and parent plants to inoculation by smut and rust									
					Type of host response to stem-rust infection					Type of host response to crown-rust infection				
					0	1	2	3	4	0	1	2	3	4
		(Symbol)	(Number)		(Plants resistant)			(Plants susceptible)		(Plants resistant)			(Plants susceptible)	
					(Crosses studied in 1935–1936)									
X 35 C C	Sel. 5541–101 × Gopher	X	1	0	...	...	...	...	1	...	...	...	1	...
		♀	5	0	...	...	3	2	...	...	...	5	...	...
		♂	3	2	...	...	...	...	3	...	...	...	...	3
X 35 C E	Markton × Sel. 5541–101	X	2	0	...	...	...	2	...	...	...	...	2	...
		♀	2	0	...	...	...	...	2	...	...	...	...	2
		♂	4	0	4	...	...	...	...	...	...	4	...	...
X 35 E C	Markton × (Seg. from X A 1131)	X	2	0	...	...	...	...	2	...	...	...	...	2
		♀	2	0	...	...	...	...	2	...	...	...	...	2
		♂	1	1	...	...	...	...	1	...	...	...	...	1
X 35 F A	(Seg. X 34 CD) × (Seg. from X 3110)	X	1	0	1	...	...	...	...	...	...	...	...	1
		♀	1	0	1	...	...	...	...	...	...	1	...	...
		♂	1	0	...	...	...	...	1	...	...	...	1	...
X CS 35 N	Kan. Sel. 333638 × Sel. 5541–104	X	1	0	...	...	1	...	...	...	1	...	...	...
		♀	4	0	...	...	...	...	4	...	...	...	...	4
		♂	5	0	5	...	...	...	...	...	4	1	...	...
X CS 35 A L	Kan. Sel. 303644 × Sel. 5541–104	X	1	0	...	...	...	1	...	...	...	1	...	...
		♀	5	0	...	...	...	...	5	...	...	...	...	5
		♂	5	0	...	...	...	...	...	...	...	5	...	...
X CS 35 A O	Kan. Sel. 303636 × Sel.5541–104	X	1	0	...	...	1	...	...	...	...	1	...	...
		♀	6	0	...	...	...	...	6	...	...	...	...	6
		♂	6	0	6	...	...	...	...	...	...	2	4	...
X 35 F K	Sel. 5543–104 × Ks. Sel. 303635	X	1	0	1	...	...	...	...	...	...	1	...	...
		♀	3	0	3	...	...	...	...	...	3	...	...	...
		♂	5	0	...	...	...	...	5	...	...	...	...	5
X 35 D D	(Seg. from X 3012) × Ks. Sel. Row 2793	X	1	0	...	...	1	...	...	...	...	...	1	...
		♀	1	0	...	...	...	...	1	...	...	...	1	...
		♂	5	0	...	...	...	5	...	...	...	...	...	5

[a] In F_3 all bred similarly for rust resistance.
[b] This plant proved to be a self.
[c] A possible error in reading in 1934–35.

of each hybrid was sown per pot, although, usually, the seed of a given parental line was sown at the rate of 4 to 6 seeds per pot.

The methods employed in growing the plants and inoculating them with rusts and smuts were those usually followed in the experimental greenhouse culture of oats. Before inoculating with smut, the hulls were removed from the kernels of parental lines, but, because of the value and the extreme scarcity of seed, the hybrid kernels were not hulled. The seeds were blackened with smut spores and then sown. For a few days following inoculation and planting of the seed, the greenhouse temperature was maintained at from 70° to 80° F. This procedure thus far has been highly satisfactory in obtaining smut infection of oats under greenhouse conditions. The smut inoculum depended upon the parents of each individual cross. Crosses involving only those varieties adapted to the Corn Belt were inoculated with smut collected in that area. Seed of crosses involving northern midseason white, Fulghum, and Red Rust-proof types was inoculated with smuts originally obtained from oats of these respective varietal types in areas where they are grown commercially.

Before inoculating adult plants with rust in the greenhouse, a tent of muslin was erected over the plants. They were then sprayed with an atomized stream of tap water until thoroughly wet. The floors, beds, walls, and soil beneath the beds were all thoroughly wetted to help maintain a saturated atmosphere. To further provide optimum moisture conditions, the pet cocks of the steam radiators were partly opened to allow escape and condensation of steam. All ventilators of the greenhouse were closed and a temperature of 70° to 90° was maintained for 24 hours after inoculation.

Urediospores of the rust mixed with talcum powder, an innocuous dust, were then dusted over the plants by means of a syringe bulb adapted to the purpose. Talcum powder, because of its visibility, enables the operator to note the volume and distribution of the inoculum.

Puccinia coronata avenae, race 1, and *P. graminis avenae*, race 2, were employed each year for inoculation. The inoculum was furnished by H. C. Murphy, of the Iowa Agricultural Experiment Station, Ames, Iowa.

RESULTS

Reaction of F_1 Plants to Smut

Data presented in table 1 show that widely different oat types were used as parents in the crosses included in the study of smut and rust resistance of F_1 plants in 1934–35; yet not one of the 28 F_1 plants showed any susceptibility to smut. This was true even in those 9 crosses of which one or the other parent proved to be smut-susceptible.

Likewise, in the results obtained from the 9 crosses grown in 1935–36, although one or the other of the parents was smut susceptible in 2 of the 9

[e] A possible error in reading in 1934–35.

crosses, none of the F_1 plants was infected. Consequently, in these 26 crosses, one or the other parent proved susceptible in 11 crosses; yet not a single F_1 plant produced any smut. This absence of smut in the F_1 may have been due to the fact that the seed of the parent varieties was hulled when inoculated, while the F_1 seed was not. It is our opinion, however, that the dominance of resistance over susceptibility to smut in the F_1 plants of these crosses was due to genetic factors for resistance rather than to the fact that the hulls were not removed from the crossed seed. The dominance of resistance over susceptibility to smut infection in F_1 would, therefore, seem evident from the reaction of these crosses.

Reaction of F_1 Plants to Stem Rust

The reaction to stem rust (*Puccinia graminis avenae*, race 2) of F_1 plants of 17 crosses was studied in 1934–35. These studies indicated that where both parents were resistant to stem rust the progeny also were resistant, although notably heterozygously so in one cross. In crosses in which only one parent was resistant to stem rust, the hybrid progeny were resistant, although the F_1 plants of 2 crosses gave a variable reaction, in that some plants appeared to be susceptible to stem rust.

Results of studies made in 1935–36 were similar to those obtained in 1934–35, but much less conclusive. The rust epiphytotic obtained in the greenhouse in 1935–36 was of such severity as would rarely occur naturally under field conditions. Even the most stem-rust-resistant varieties, such as Richland, showed considerable infection. Record was made of the stem-rust infection observed on the F_1 plants of 9 crosses in 1935–36.

In no case were both parents of any of these crosses resistant to stem rust. In 7 crosses, one of the parents was resistant; the other parent was susceptible. Study of the F_1 progeny of 7 crosses showed that 4 plants were resistant and 3 susceptible. In one cross, both parents gave a susceptible reaction, yet the F_1 progeny appeared to be resistant. In one cross, plants of both the parental and the F_1 progeny were susceptible to stem rust.

The data obtained as the result of the 2-year study of 26 crosses indicate that the inheritance of stem-rust resistance in most cases is dominant in F_1 oat plants.

Reaction to Crown Rust

A study of host reaction by F_1 oat plants to crown rust was conducted at the same time and on the same plants inoculated with stem rust. The results, however, were less conclusive than those obtained from stem rust. In only one cross of the 17 studied in 1934–35, both parents and F_1 hybrids were resistant to crown rust. In 14 other crosses, one or the other of the parents was resistant, and in 2 other crosses, one parent was heterozygously

resistant and the other was susceptible. When one parent was either homozygously or heterozygously resistant to crown rust, plants of the F_1 progeny were resistant in all except 2 crosses in which one of the F_1 plants was resistant, while the others were susceptible. In this cross, both parents reacted heterozygously for both crown rust and stem rust.

The results obtained in 1935–36 differed widely from those obtained in 1934–35 in that the rust epiphytotic obtained was especially severe and only the most resistant oat types gave the *resistant type* of reaction to crown rust.

A total of 9 crosses was studied. In 2 of these crosses, both the parents and the F_1 progeny were susceptible to crown rust. In 6 crosses, one of the parents was resistant and the other susceptible. The F_1 progeny of these combinations resulted in 3 crosses producing resistant and 3 susceptible progeny, a result very different from what might have been expected on the basis of the previous year's study. A resistant F_1 progeny resulted from the cross in which one parent was resistant and the other was heterozygously resistant to crown rust. Regardless of the exceedingly heavy infection of crown rust in 1935–36, the fact remains that resistance in the F_1 frequently proved to be dominant.

A notable point in connection with studies on the reaction of parent and progeny to stem and crown rusts is that, usually, the F_1 plants approximated the more resistant parent in type of reaction to rust.

SUMMARY AND CONCLUSIONS

From a study of the reaction of F_1 oat plants and of plants of each parental strain to smut and inoculation of the adult plants with spores of stem and crown rusts, the following results were indicated.

Although parents and progeny were not treated alike, resistance to smut apparently is dominant in F_1 oat plants.

Resistance to stem rust usually was dominant in F_1 plants, although subject to some variation.

Resistance to crown rust usually was either dominant or intermediate in F_1 plants, but the apparent dominance was less pronounced than was resistance to stem rust.

Resistance to either rust in F_1 individuals of certain crosses tended to approximate the type of resistance observed in the more resistant of the parental lines.

RECENT DEVELOPMENTS IN POTATO BREEDING FOR RESISTANCE TO VIRUS DISEASES[1]

E. S. Schultz,[2] C. F. Clark,[3] W. P. Raleigh,[4] F. J. Stevenson,[5] Reiner Bonde,[6] and J. H. Beaumont[7]

(Accepted for publication July 6, 1936)

INTRODUCTION

Resistance to virus diseases in potato varieties has been observed for some time and recently it has been shown[8] that resistance to one of these diseases, mild mosaic, is heritable. Further evidence of this and the results of breeding for resistance to other viroses are recorded in this paper.

Experiments have shown that potato seedlings vary in their reaction to virus diseases. Some of them fail to contract the virus either by field exposure or by grafting. Others rarely contract the virus in the field, but become infected in the graft tests, still others contract the virus readily, both by field exposure and by grafting.

Since it is important to determine whether or not seedlings will become infected naturally, field exposure as well as grafting were used in breeding for disease resistance.

METHODS OF INOCULATION

Field exposure.—In the field exposure tests 10 to 20 hills of each seedling or variety were planted in rows adjacent to a row of mosaic plants, so that transmission by insect vectors was favored. Healthy Green Mountains were planted as a control with each 10 lots of seedlings. In seasons of light aphid infestation, colonies of aphids were distributed over the mosaic plants at blossom time to supplement natural infestation. As a further aid to the spread of the disease the tops of mosaic plants were cut off and placed along the rows of the seedlings 4 weeks before harvest.

[1] Conducted as a cooperative project between the Bureau of Plant Industry, U. S. Department of Agriculture, the Maine Agricultural Experiment Station and the Maryland Agricultural Experiment Station.

[2] Senior Pathologist, U. S. Dept. of Agriculture.

[3] Horticulturist, U. S. Dept. of Agriculture.

[4] Associate Pathologist, U. S. Dept. of Agriculture.

[5] Senior Geneticist, U. S. Dept. of Agriculture.

[6] Associate Pathologist, Maine Agric. Exp. Sta.

[7] Formerly Head of Dept. of Horticulture, Maryland Agric. Exp. Sta.

[8] Schultz, E. S., C. F. Clark, R. Bonde, W. P. Raleigh and F. J. Stevenson. Resistance of potato to mosaic and other virus diseases. Phytopath. **24**: 116–132. 1934.

The diseased seed potatoes, which provided the inoculum of a particular virus, were propagated in isolated tuber-unit seed plots and were rogued for other viroses.

The seedlings and controls were harvested by hand, and 2 tubers per hill from 10 hill lots, or 1 tuber per hill from 20 hill lots, were reserved for planting the following season when observations on the number of infected plants were made. Inasmuch as different varieties may vary in symptom expression to the same virus, representative samples of seedlings that contracted mosaic in the test plot were grafted onto healthy Green Mountain or Green Mountain seedlings for final diagnosis of the mosaic type.

Tuber and shoot grafts.—Tuber grafts were made by the core-graft method. Shoot grafts were made by in-arch grafting when the plants were 6 to 8 inches above the soil.

REACTION OF POTATO TO LATENT MOSAIC

In 1932, 65 hills each of a Green Mountain seedling, Katahdin, and seedling 41956, were grown on Aroostook Farm, Presque Isle, Maine. The hills of each of these varieties were alternated in the row with hills of Triumph that carried latent mosaic. In another series an equal number of hills of Katahdin and the 2 seedlings were grown in rows not adjoining the latent mosaic plants. Shortly after these plants had blossomed the tops of 12 hills of each of the 3 varieties not planted next to the latent mosaic plants were brushed with latent mosaic Green Mountain foliage. At harvest 2 tubers per hill from both series of tests were reserved for planting and observation in 1933. The plants grown from these tubers were tested for latent mosaic by leaf-rubbing inoculations made on Jimson weed, *Datura stramonium* L.

The results of these inoculations disclosed that Katahdin and seedling 41956 had not contracted latent mosaic in either the foliage brushing or the contact tests. In contrast to this, 70 per cent of the plants of the Green Mountain seedling became infected when grown in contact with the Triumph variety having latent mosaic, and 33 per cent became infected when grown in contact with latent mosaic Green Mountain. Inoculation by the leaf-brushing method, using latent mosaic Green Mountain foliage as the source of the inoculum, caused 58 per cent infection. Although Katahdin failed to contract latent mosaic in either the contact or leaf-brushing tests, this variety has been infected by leaf-mutilation inoculations. Inasmuch as the Green Mountain seedling, when introduced into these exposure tests, was free from latent mosaic, these results indicate that this seedling readily contracts latent mosaic if grown in contact with latent mosaic plants, or if rubbed with foliage infected with latent-mosaic virus. These results also show that Katahdin and seedling 41956 are highly resistant to latent mosaic in field-exposure tests.

For 6 consecutive seasons 100 hills each of Katahdin and of seedling 41956 were propagated in rows adjoining rows of latent-mosaic potatoes. During this period seedling 41956 failed to contract latent mosaic, while a few plants of Katahdin and every plant of the Green Mountain seedling did contract it.

Although Katahdin contracted latent mosaic in only a few plants in the field-exposure tests, this variety easily became infected in tuber and shoot grafts onto latent-mosaic Green Mountain, and, as a result, developed severe top necrosis. In tuber grafts some of the Katahdin shoots are killed at different stages of development, while other shoots manifest necrosis and more or less irregular and interveinal light green areas. Tubers from such infected Katahdin shoots develop plants manifesting a few necrotic spots and irregular light green patches on the leaves. Subsequent shoot and tuber grafts of the mottled Katahdin onto latent-mosaic Green Mountain failed to induce top necrosis. Oortwijn Botjes[9] reported similar results with certain European potato varieties. To determine the breeding behavior of Katahdin with respect to its reaction to latent mosaic, 100 seedlings of Katahdin naturally fertilized were in-arch grafted onto latent-mosaic Green Mountain seedlings. Fifty-seven of the Katahdin seedlings developed top necrosis. The other 43 failed to show these symptoms. It is possible that these may have escaped infection since it was not definitely known that every Green Mountain seedling onto which these were grafted harbored latent mosaic. It is interesting to note, however, that 57 per cent of the Katahdin seedlings manifested latent mosaic as top necrosis similar to the reaction of the Katahdin parent in graft tests.

In addition to the 6-year field-exposure tests several hundred plants of S 41956 have been given the more severe inoculation tests of leaf-rubbing and grafting. Up to the present time not a single plant of this seedling has contracted latent mosaic, as shown by the failure of Jimson weed and Green Mountain seedlings to become infected when return inoculations were made to them from grafted or rubbed plants. This evidence indicates that S 41956 is completely resistant to latent mosaic.

REACTION OF POTATO TO VEINBANDING MOSAIC

The results of the veinbanding-mosaic resistance tests in the field are not conclusive. During the last 3 seasons at Presque Isle, Maine, only 15 per cent of the Green Mountain plants showed this disease in the field-exposure tests, some of the 20-hill Green Mountain controls escaping infection completely. In the tuber-graft tests with the veinbanding mosaic no

[9] Oortwijn Botjes, J. G. Attenuation of the virus of top necrosis (Acro-necrosis, healthy potato virus) and acquired immunity of potato varieties to this virus. Tijdschr. Plantenziekten **39**: 249–262. 1933. [In Dutch. English summary, p. 260–261.]

seedling has yet been found that failed to contract the disease. It was observed, however, that the seedlings varied greatly in the expression of symptoms as a result of their reaction to the veinbanding virus. Three types of reaction were observed: (1) slightly rugose, (2) veinclearing and rugose, and (3) severe necrosis with veinclearing and rugose. In 1934 5 tubers of each of 23 different seedlings were tuber-grafted onto veinbanding mosaic seedling 42898, which shows this mosaic as a slight rugosity of the leaves. All the seedlings contracted the disease, but the infection varied from less than 50 to 100 per cent. This difference probably is not due to inherent differences between the seedlings but to failure of a healthy piece of tuber to unite closely with a diseased section. The grafted seedlings developed veinclearing and necrosis, manifestations of the more severe reactions of potato to the veinbanding mosaic virus.

In 1935, 25 seedlings were given the same test for veinbanding as that described for 1934, with very similar results. All 25 contracted the disease in from 40 to 100 per cent of the tubers grafted. Again, a great variation in symptom expression was observed. Two seedlings manifested severe streaking and rugosity, while 2 others, the progeny of a different cross, developed slightly more rugose leaves than those of the healthy plants.

The wide variation in reactions of these different potato seedlings to veinbanding mosaic indicates the possibility of producing seedlings that will be tolerant or highly resistant to veinbanding mosaic.

REACTION OF POTATO TO MILD MOSAIC

It was indicated previously[8] that the reaction of different potato varieties and seedlings to mild mosaic varied greatly and could be grouped as follows: (1) Highly resistant, (2) seldom contracting mild mosaic in the field, but becoming infected in tuber grafts, (3) manifesting milder symptoms than Green Mountain, and (4) contracting mild mosaic as readily as Green Mountain and expressing symptoms not unlike those of this variety. It was indicated, too, in the field-exposure tests of 1932, that the genetic behavior of seedling varieties differs widely, as shown by the resistance of their progenies. Of the 464 seedlings of Katahdin naturally fertilized, grown in plots of 20 hills each, only 33 seedlings, or 7 per cent of the total, contracted mild mosaic. Of the 75 seedlings of S 43752 naturally fertilized, 21, or 28 per cent, contracted the disease. In contrast to this, 54 10-hill lots of Green Mountain, planted as controls, contracted mild mosaic in every lot. A similar field-exposure test of the apparently resistant seedlings of both of these progenies has since been completed.

In this test mild mosaic was contracted in 2 per cent of the 369 naturally fertilized Katahdin seedlings, in 14 per cent of the 43 naturally fertilized

S 43752 seedlings, and in every Green Mountain check. The combined results of the 2 field-exposure tests are recorded in table 1.

TABLE 1.—*Resistance to mild mosaic as shown by the results of two field-exposure tests of the progenies of Katahdin and S 43752 naturally fertilized*

Parentage of seedlings	Varieties	Lots		
		Total	Mosaic	
			No.	Per cent
Katahdin naturally fertilized	464 seedlings	464	42	9
S 43752, naturally fertilized	75 "	75	28	37
	Green Mountain controls	89	89	100

To determine whether or not the seedlings in these progenies that failed to show mild mosaic symptoms, after 2 seasons of field exposure, carried this disease, 100 of these seedlings of the progeny of Katahdin, naturally fertilized, were in-arch grafted to a Green Mountain seedling. The results showed that none of these Katahdin seedlings had contracted mild mosaic in the field-exposure tests. These same seedlings were in-arch grafted to a mild mosaic Green Mountain seedling. Thirty-eight per cent of them contracted mild mosaic in these graft tests. It is evident from the results with this progeny that, although seedling varieties are resistant under field-exposure tests, they may be susceptible in the more severe in-arch grafting tests. The in-arch grafts have not been carried far enough to determine whether or not any of the seedlings would be found resistant in such tests. The 62 per cent of the 100 Katahdin seedlings that failed to contract the disease in these tests may not be resistant; they may have escaped, only.

In a further study of the mild-mosaic resistance of Katahdin this variety was crossed with No Blight, a variety that shows some degree of resistance to late blight. The progeny of this cross, consisting of 347 seedlings, was exposed to mild mosaic on Aroostook Farm in 1934. The results of this test are given in table 2.

These results show that 86 per cent of the progeny of No Blight × Katahdin remained healthy, whereas every one of the Green Mountain seedlings and Green Mountain controls became infected with mild mosaic. Eight of the No Blight × Katahdin seedlings resistant to mild mosaic were also found to be highly resistant to late blight, as shown in greenhouse and field plot tests.

Katahdin has shown resistance to mild mosaic in field-exposure tests for a number of years. That it is not homozygous for this character is shown

TABLE 2.—*Resistance to mild mosaic as shown by the progeny of a cross between No Blight and Katahdin in a field exposure test*

Parentage of seedlings	Varieties	Lots		
		Total	Mosaic	
			No.	Per cent
No blight × Katahdin	347 seedlings	347	48	14
Green Mountain naturally fertilized	17 "	17	17	100
	Green Mountain controls	34	34	100

by the 9 per cent susceptibles in the selfed progeny. That the character is inherited as a dominant is shown both by the selfed progeny and the No Blight × Katahdin cross, which gave a ratio of apparently resistant to susceptible seedlings of 86 to 14, which ratio may, of course, be modified somewhat in further tests with this cross.

Reaction of Potato Seedlings and Varieties to Spindle Tuber

In 1933, 9 hills of each of 120 seedlings, selections from 24 different crosses, in addition to 99 nine-hill lots of South American varieties and 33 nine-hill lots of Green Mountains, were exposed to spindle-tuber Green Mountains planted in adjacent rows on the University of Maryland Farm, near Berwyn, Md.

At harvest time 3 hills per lot were harvested and reserved for planting in 1934.

Observations in 1934, on the material harvested from these exposed lots, showed that 71 per cent of the seedlings, 58 per cent of the South American varieties, and 81 per cent of the Green Mountain controls had contracted spindle tuber.

In 1934, nine-hill lots of 238 South American varieties were propagated in rows adjoining rows of spindle-tuber Green Mountain. Only 74 of the South American varieties developed tubers from which 2 tubers per hill were saved for planting in 1935; 2 tubers per hill were also saved from the 35 Green Mountain control lots. The results in 1935 showed that 57 per cent of the South American lots showed spindle tuber and 89 per cent of the Green Mountains had contracted the disease.

In 1935, 880 seedlings representing selections from a number of crosses and inbred lines were tuber-core grafted onto spindle-tuber Katahdin. Since spindle tuber is transmitted easily by this method only 3 tubers per seedling were grafted. One healthy tuber per seedling and the remainder of the tubers used as the source of inoculum were planted as checks. The results

showed that 61 per cent, or a total of 537 seedlings, had contracted spindle tuber in every tuber grafted; that 38.6 per cent, or 340 seedlings, developed spindle tuber in only 1 or 2 of the 3 grafted tubers, and that 1.5 per cent, or 13 seedling lots resulting from 4 different progenies, failed to contract this disease. Since it is possible that the 13 healthy seedlings merely escaped infection, additional grafts will be made to determine whether or not they are resistant. Different seedlings showed different symptoms, varying from slightly dwarfed, somewhat spindling and sparse shoots, to severely dwarfed and curled tops. Some seedlings were so tolerant that it required critical observation to detect the difference between the diseased and normal plants. To find such wide differences between sibs in their symptom expressions is important from the plant-breeding standpoint.

Reaction of Potato Varieties and Seedlings to Leaf Roll

In 1933 and 1934, field-exposure tests were conducted to determine the reaction of various potato seedlings, commercial varieties and South American varieties to leaf roll at the University of Maryland Farm, near Berwyn. Thus far, the results are not conclusive, for, while many of the seedlings and other varieties escaped infection, a large percentage of the susceptible Green Mountain controls also failed to contract the disease. The lack of infection in the seedling and South American varieties, therefore, could not be attributed to resistance. It will be necessary to develop a more efficient method of testing or find a location where leaf-roll spread is so general that at least every susceptible control lot contracts the disease. If better conditions for spread are not found, tuber-graft tests may have to be resorted to. The objection to using the graft method only is the possibility that some seedlings might contract the disease in such a test and might very rarely contract it in a field-exposure test, a situation analogous to that found in the resistance of Katahdin to mild mosaic. In the leaf-roll tests, as in the spindle-tuber tests, a wide variation is found in the reaction of the various seedlings to the disease. Some of the diseased plants are almost normal in appearance; others are dwarfed and discolored, and show a far greater rolling of the foliage. If varieties cannot be found that will not contract the disease, some may be found that are highly tolerant to it.

SUMMARY

Data on the inheritance of resistance to mild mosaic and the reaction of seedlings and varieties to other viroses, such as latent and veinbanding mosaics, leaf roll and spindle tuber in field-exposure tests, as well as in tuber and shoot grafts, are recorded.

Potato varieties and seedlings vary in their reaction to viroses; some are completely resistant; some fail to contract the virus in the field, but become

infected in graft tests; others rarely contract the virus in the field but become infected in grafts; still others contract the virus readily both by field exposure and by grafts. In the experiments with latent mosaic S 41956 never contracted this disease either by field exposure leaf rubbing or in grafts in tests of several hundred plants. Katahdin was highly resistant to latent mosaic in the field, but became infected with the virus by grafting.

No definite evidence of resistance to veinbanding mosaic was found in any of the varieties or seedlings tested, but there was a great variation in the severity of symptoms produced. Some seedlings manifested severe streaking and rugosity, while others, the progeny of another cross, developed only slightly more rugose leaves than those of the healthy plants. Katahdin has been completely resistant to mild mosaic in field-exposure tests for a number of years. That this resistance is heritable was shown in (8), and further evidence confirming this is given in this paper. That Katahdin is not homozygous for this character was shown by the fact that 9 per cent of the seedlings in a selfed progeny were susceptible. The progeny of the No Blight × Katahdin cross gave a ratio of apparently resistant to susceptible of 86 : 14.

A total of 120 seedlings, selections from different crosses and inbred lines, and 337 lots of South American varieties were exposed to spindle tuber during 1933 and 1934. The results showed some variation in the amount of spread found in different seedlings, but, since the control plants did not all become infected, it was difficult to determine whether the plants remained healthy because of resistance or whether it was only a case of escape. Most of the 880 seedlings, tuber-grafted with spindle tuber in 1935, became infected. It has not yet been determined whether the few that failed to become infected escaped or were resistant. It was found, however, that there is a great variation in symptoms produced on the different varieties, varying from severely dwarfed and curled tops, to such mild symptoms as to require critical observation to detect the disease.

Field exposure tests in 1933 and 1934 to determine resistance to leaf roll proved to be unsatisfactory, since only a small amount of spread took place even in susceptible control plants. Transmission by tuber grafts has shown that there is a wide variation in the reaction of the different seedlings to this disease. Some are dwarfed and discolored, and show considerable rolling, while others are almost normal in appearance.

The variations of symptoms of spindle tuber and leaf roll, as expressed in different seedlings, indicate that if varieties cannot be found that will not contract these diseases, some may be found that are highly tolerant to them.

THE NEED OF PERMANENT REFERENCE COLLECTIONS OF INSECT VECTORS OF PLANT DISEASES

FLOYD F. SMITH

(Accepted for publication July 8, 1936)

Insect collections were originally formed, maintained, and built up purely for taxonomic purposes, and large collections are now being amassed with this object primarily in mind. In a recent paper, however, Osborn (15) has pointed out various needs for entomological collections, in addition to those of pure taxonomic research, in which attention to taxonomic problems is fundamental to permanent advances in related branches of science. He also has stressed the importance of insect collections, with their type specimens, when species described by earlier workers are under investigation, since such species often are described so inadequately that they cannot possibly be identified solely from the descriptions. This is especially true in cases where discovery of related forms has brought to light many species any one of which would meet the specifications given in the early description.

At the present time our lists of known insect species are rapidly lengthening. Taxonomic workers recognize the probability that in future years many of our recently written descriptions of insects may prove inadequate for separating them from closely related forms that will doubtless be discovered, just as descriptions made a century or less ago often are found too brief for recognition of the species today. As pointed out in later paragraphs, the misidentification of species already described or the lack of agreement among taxonomists adds to the confusion.

Most entomologists realize that problems will arise from the continuously increasing literature of descriptive entomology and also the present taxonomic confusion, particularly in certain groups of insects, and some of the workers are now taking steps to preserve, for future reference, representatives of the forms upon which they are conducting biological or other studies. Such specimens will be permanently available as a means of identifying the species upon which their published work was based.

In the study of virus diseases of plants, the importance of the relationship of insects to the spread of the causal viruses is becoming more generally recognized. Kunkel (12, p. 350), in 1928, stated that "the most important factor in the spread of virus diseases is their transmission by insects. Many have been proved to be so transmitted and it is probable that all are spread in this way. . . . The more these maladies are studied, the more evident it becomes that epiphytotics of virus diseases are related to the fortunes of

insect colonies of the species concerned in the transmission of these diseases." Johnson and Hoggan (10, p. 330) indicated their realization of the importance of the specificity of insect vectors when they stated that the specific vector concerned is frequently the main criterion for identification of a plant virus. Storey (20) further emphasizes the importance of the insect in relation to certain virus diseases and cites a number of cases in which the virus is most readily identified by means of the insect vector. In separate papers Elze (5) and Storey (20) suggest classifications of viruses on the basis of the insect vector. In recent papers Kunkel (13) and Leach (14) discuss the relation of insects to the classification of plant diseases.

A resolution taking steps toward laying the foundation for an adequate classification of plant viruses, recently adopted by The American Phytopathological Society (3), indicates that a study of their insect vectors should be included. At the present time confusion exists as to the identity of certain insects that have been reported as being vectors of virus diseases.

Allard (1, p. 27) reported that *Macrosiphum tabaci* (Pergande) transmitted the mosaic disease of tobacco. No aphid by this name is known, and Patch (16, p. 29) states that *Macrosiphum tabaci* (Pergande) is a synonym of *M. solanifolii* (Ashmead). The "types" of *tabaci* are in the National Museum collection, and P. W. Mason states that they are undoubtedly the same species as *solanifolii*. In a later paper Allard (2, p. 627) stated that *Myzus persicae* (Sulz.) also transmitted tobacco mosaic. Hoggan (7, 8) found that *M. persicae* failed to transmit the virus of true tobacco mosaic from any host. *Macrosiphum solanifolii* transmitted this virus from tomato but not from tobacco. The same author found that both species of aphids readily transmitted the virus causing cucumber mosaic to all susceptible hosts and, on the basis of the insects concerned, concluded that this virus might have been the one, instead of true tobacco mosaic virus, that Allard reported as disseminated by the aphids. Johnson (9, p. 747), however, intimated that, since true tobacco-mosaic virus is highly infectious, mechanical transmission could have accounted for the spread of this disease. On the basis of work by Hoggan (7, 8) and Johnson (9), it is possible that Allard was concerned with either one or both of the viruses, depending upon the precautions he took in conducting the insect-transmission tests.

In America several viruses have been found to be transmitted by *Macrosiphum solanifolii*, while in England *M. gei* (Koch) is reported as transmitting what appear to be the same and also other viruses. Theobald (21, p. 108) reported that *M. solanifolii* was a synonym of *M. gei*. On this basis K. M. Smith (18, pp. 109, 113, 117), in his summary of the virus diseases, grouped the American work on viruses reported to be transmitted by *solanifolii* with the European work on the same problem under the one species name, *M. gei*. More recently, Hille Ris Lambers (6), after studying Theo-

bald's aphid collection, concluded that *M. gei* and *M. solanifolii* were distinct species. Because of the differences in the ability of closely related species of aphids to transmit plant virus diseases (8, 20), it seems unwise to lump this work until the matter of specific identity has been positively settled.

The vector of tomato spotted wilt in Australia originally identified as *Frankliniella insularis* (Franklin) is now considered to be an undescribed new species (19).

The vector of the virus causing aster yellows in America was formerly called *Cicadula sexnotata* (Fallén), an insect that is generally distributed in Europe, but the aster yellows is not known in Europe (11, pp. 655, 699). Dorst (4, p. 40) showed that the vector is a different species, *C. divisa* (Uhler).[1] According to our present knowledge *C. sexnotata* occurs only in Europe and *C. divisa* only in America, which appears to explain why aster yellows is a problem on this continent and not in Europe.

In certain papers the insect vector has been identified only to the genus, or even only to the family or order (17, p. 20), which of course lessens the value of the work from an entomological as well as a pathological standpoint.

No adverse criticism is intended of any work herein cited or of the many other references of a like nature that could have been included, for circumstances often are such that a worker cannot obtain identification of insect material before his paper goes to press, and in some cases the taxonomy of the group to which the insect belongs is in a chaotic condition.

Little uncertainty exists as to the identity of some species of insect vectors, but there is much confusion in other instances, and the question regarding the particular species concerned appears to be much involved and a subject of controversy.

To be certain of the specific identity of an insect vector is just as important in the problems of identification and means of dispersion of a given virus disease as in those problems presented by any other injurious insect. Whenever, in pathological experiments, the ability of an individual insect to transmit a particular virus[2] has been demonstrated, the insect involved seems to possess a value to the virus problem approaching that of a type as designated by a taxonomist describing a new species, and representatives of such specimens should be preserved for future reference. This is especially important when there is any doubt as to the identity of the species represented, or when it belongs to a group in which related species might be confused.

[1] In a more recent paper now in manuscript form, Dorst states that this species should be known as *Macrosteles divisus* (Uhler).

[2] The author agrees with the following comment by Dr. F. W. Poos, who reviewed this manuscript: "Although the virus diseases are admittedly most concerned, much of the material presented applies as well to bacterial and fungous diseases."

In the publication of the results of transmission tests an author could indicate the location of representatives of the experimental insects together with the accession number or other data by which the material may be located. The insects selected for preservation could be taken from any of the controlled experiments where positive results were obtained, particularly if from pure-line-bred stock. Whenever insects are submitted to the taxonomist for identification, ample material should be included, so that he will have no excuse for not returning duplicates if the experimenter is interested in having them for reference or exchange.

The larger entomological museums are becoming better equipped to preserve insects such as those used in biological, control, or virus studies, and facilities are improving whereby loans can be arranged, or comparisons made with insects of other countries. Since much of the work with insect transmission of virus diseases is comparatively recent, and since many of the original workers in this field are still actively engaged on their problems, it appears that most representatives of the known insect vectors of the many plant diseases could be made available for safekeeping and future reference in designated museums.

It seems particularly desirable that one or more leading institutions conducting research on virus diseases should bring together representatives of all available bona-fide, present-known insect vectors of plant viruses and serve as repositories for such material from future investigators. It is further suggested that individual workers keep available in their laboratories representative material with which they have worked until proper repositories become available.

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE,
U. S. DEPARTMENT OF AGRICULTURE,
NATIONAL AGRICULTURAL RESEARCH CENTER,
BELTSVILLE, MD.

LITERATURE CITED

1. ALLARD, H. A. The mosaic disease of tobacco. U. S. Dept. Agr. Bull. 40. 1914.
2. ———. Further studies of the mosaic disease of tobacco. Jour. Agr. Res. [U. S.] 10: 615–632. 1917.
3. BARSS, H. P. Report of the summer meeting of The American Phytopathological Society, June 25–27, 1935. Phytopath. 26: 74–75. 1936.
4. DORST, H. E. Studies on the genus Cicadula (Homoptera, Cicadellidae). Jour. Kansas Ent. Soc. 4: 39–48. 1931.
5. ELZE, D. L. The relation between insect and virus as shown in potato leaf roll, and a classification of viruses based on this relation. Phytopath. 21: 675–686. 1931.
6. HILLE RIS LAMBERS, D. Notes on Theobald's "The plant lice or aphididae of Great Britain." Stylops 2: 169–176. 1933.

7. HOGGAN, I. A. The peach aphid (*Myzus persicae* Sulz.) as an agent in virus transmission. Phytopath. 19: 109–123. 1929.
8. ————. Further studies on aphid transmission of plant viruses. Phytopath. 21: 199–212. 1931.
9. JOHNSON, J. Some points of view on the plant virus problem. Phytopath. 16: 745–751. 1926.
10. ————, and I. A. HOGGAN. A descriptive key for plant viruses. Phytopath. 25: 328–343. 1935.
11. KUNKEL, L. O. Studies on aster yellows. Amer. Jour. Bot. 13: 646–705. 1926.
12. ————. Virus diseases of plants, In Rivers, T. M., Ed., Filterable viruses. pp. 335–364. Williams & Wilkins Co., Baltimore. 1928.
13. ————. Possibilities in plant virus classification. Bot. Rev. 1: 1–17. 1935.
14. LEACH, J. G. Insects in relation to plant diseases. Bot. Rev. 1: 448–466. 1935.
15. OSBORN, H. The place of entomological collections in entomological research. Ann. Ent. Soc. Amer. 28: 56–59. 1935.
16. PATCH, E. M. Potato aphids. Maine Agr. Expt. Sta. Bull. 323. 1925.
17. PIERCE, W. H., and C. W. HUNGERFORD. Symptomatology, transmission, infection and control of bean mosaic in Idaho. Idaho. Agr. Expt. Sta. Res. Bull. 7. 1929.
18. SMITH, K. M. Recent advances in the study of plant viruses. 423 pp. J. & A. Churchill, London. 1933.
19. STEELE, H. V. Thrips investigation: some common thysanoptera in Australia. Australian Council Sci. and Indus. Pamphlet 54. 1935.
20. STOREY, H. H. The bearing of insect-vectors on the differentiation and classification of plant viruses. Compt. Rend. 2d Cong. Internatl. Path. Compar., Paris, 1931. 2: 471–479. 1932.
21. THEOBALD, F. V. The plant lice or aphididae of Great Britain. Vol. 1. Headley Brothers, Ashford, Kent and London. 1926.

SOME EFFECTS OF THE ENVIRONMENT ON THE SPONGY DRY ROT OF APPLES[1]

STEPHEN DIACHUN[2]

(Accepted for publication August 10, 1936)

A close similarity has been reported between the common black rot of apple fruit and the spongy dry rot. Stevens and Hall[3] stated in their original description of the spongy dry rot that "unless the spot be quite old, the disease might readily be considered to be the ordinary black rot, caused by *Sphaeropsis*, and doubtless often passes for it". They point out that in the older spots the pimples are beset with stiff black hairs that "constitute the distinctive character of this disease and serve to separate it with ease and certainty from the Sphaeropsis rot".

The experiments here reported show that these distinguishing setae are not always present and that environmental conditions may be important in influencing the nature of the symptoms. Under some conditions the two diseases are very similar, while under other conditions they can be recognized and separated readily. Stevens and Hall named the causal agent *Vollutella fructi*, and the rot is still often called the Volutella rot. Saccardo, however, transferred the fungus to the genus Colletotrichum, due to the fact that it has black setae and acervuli that are at first subcuticular.[4] According to Duke the genus Volutella is distinct from Colletotrichum because Volutella "has a superficial origin and small oval spores and hyaline setae."[5] Therefore, sensu Duke and Saccardo, the fungus is not *Volutella fructi* but *Colletotrichum fructus* (Stevens and Hall) Saccardo, because it does form black setae and does not have oval spores, and consequently the name Volutella rot is a misnomer.

The spongy dry rot occurs in widely scattered regions. It has been reported in Massachusetts, Connecticut, Pennsylvania, New York, North Carolina, Ohio, Illinois, West Virginia, and Canada. Considerable storage

[1] Portion of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Botany in the Graduate School of the University of Illinois, 1935.

[2] The writer wishes to express grateful acknowledgment for the suggestions, criticism, and advice given by Drs. Const. J. Alexopoulos, F. L. Howard, C. F. Hottes, and N. E. Stevens.

[3] Stevens, F. L., and J. G. Hall. Some apple diseases. North Carolina Agr. Expt. Sta. Bull. 196. 1907.

[4] Saccardo, P. A. Sylloge fungorum. 22: 1201. 1913.

[5] Duke, M. M. The genera *Vermicularia* Fr. and *Colletotrichum* Cda. Brit. Mycol. Soc. Trans. 13: 156–184. 1928.

rot was caused in Massachusetts[6] where the disease has been prevalent on unsprayed and wild fruit. According to Peairs and Sherwood it caused severe damage on northwestern apples in West Virginia in 1923.[7]

Colletotrichum (*Volutella*) *fructus* (Stevens and Hall) Saccardo, has been known to occur on apple fruit; it has been observed on twigs occasionally, but has not been reported on leaves. Experiments carried out under greenhouse conditions now show that the fungus does parasitize apple leaves under some conditions.

METHODS AND MATERIALS

In the present experiments Grimes Golden, Willow Twig, and Jonathon varieties of apple fruit were used in the studies on symptoms. Observations were based on apples inoculated artificially. Inoculation was obtained by puncturing the skin with a sterile needle, and introducing a water suspension of spores into the wound thus made; the inoculated fruit was incubated at room temperature for 48 hours.

In order to study the susceptibility of twigs and leaves under greenhouse conditions, young seedlings were grown from seeds of Grimes Golden apples. The plants were inoculated by spraying the leaves with a water suspension of spores. Some leaves were first wounded with a sterile needle, while others were not injured. The plants were then incubated in a moist chamber 48 hours. In addition to leaves of seedlings 4 weeks old, and 2 months old, mature leaves of seedlings 2 years old were inoculated in this manner.

The susceptibility of young twigs of seedlings 6 weeks old was determined by wounding the stem with a sterile needle, applying a spore suspension, and incubating in a moist chamber at room temperature.

OBSERVATIONS AND CONCLUSIONS

Under average laboratory conditions of moisture and temperature the inoculated apples developed symptoms as described by Stevens and Hall[3]: a firm, brown, more or less circular spot was formed 5 to 7 days after inoculation; typical setose acervuli were added to the outside of those originally formed.

Usually these setose acervuli suffice to distinguish the spongy dry rot from other diseases; but it was observed that often such acervuli were not produced. Instead, small, rounded, slightly raised, blister-like bodies were formed, which produced neither spores nor setae. At such times the brown rotted area turned dark brown or black, and the spongy dry rot then strongly

[6] U. S. Dept. Agr. Bur. Plant Indus. Plant Disease Reptr. Sup. 14: 60. 1921; 70: 204. 1929. [Mimeographed.]

[7] Peairs, L. M., and E. C. Sherwood. Orchard Spraying. West Virginia Agr. Expt. Sta. Circ. 36. 1924.

resembled the common black rot of apples (*Sphaeropsis malorum* Peck). The two diseases could be confused under these conditions, and, of course, could not be separated on the basis of setae, for setae were lacking. At low humidities, approximately 40 per cent relative humidity, setose acervuli were never observed; at high humidities, at or near saturation, setae usually were produced. However, because a few cases were observed where setae were not formed even under moist conditions, it seems that the amount of atmospheric moisture present is not the only conditioning factor, although it apparently is an important one. Even though all the reasons are not known, it was evident that there is a marked variation in the type of symptoms produced by the spongy dry rot of apples.

When leaves were sprayed with a water suspension of spores of the fungus, brown, round or irregular spots appeared 3 or 4 days after inoculation. If the plants were kept in a moist chamber the diseased area increased in size rapidly, and abundant acervuli were formed 5 or 6 days after inoculation. In several cases acervuli were present within 4 days. In a moist atmosphere the leaf became soft and flaccid and at times exuded a brown liquid in the late stages of decay. After the leaf was infected, the fungus often penetrated the petiole, and the entire leaf drooped; acervuli appeared on the petiole, as well as on both upper and lower surfaces of the blade.

The stems of the 6-week old seedlings which were inoculated, became brown and produced numerous acervuli; the fungus sometimes spread into the petiole and the basal portion of nearby leaves, and developed characteristic acervuli.

Apparently the fungus penetrates leaves directly through the epidermal layer, for healthy leaves were infected by simply applying a water suspension of spores to the leaf surface, either upper or lower. Microscopic examination showed that spores were germinating on the leaf surface. After 6 hours the germ tubes were 4 to 5 times the spore length; appressoria were observed on the leaf surface, but actual penetration was not seen. Evidently penetration may occur directly through the epidermal layer, for stomata are not present on the upper surface of the leaf.

Experiments show that a relatively high humidity is necessary for the development of leaf spots. In moist air the spots enlarged rapidly, sometimes involving the whole leaf in several days; but when the inoculated plants were removed from the moist chamber to dry laboratory air, at approximately 40 per cent relative humidity, the small spots increased in size but very slowly, and acervuli were not formed. If the plants were kept in the moist chamber until the leaves were spotted and then were removed into the dry laboratory air, infected leaves showed a tendency to curl, pucker, and dry. The diseased areas increased in size slightly, but fruit bodies did not develop.

For the appearance of the disease on apple leaves, and for the formation of the setose acervuli on the fruit, it seems that under laboratory conditions, a high degree of atmospheric moisture is necessary.

SUMMARY

The spongy dry rot of apples, *Colletotrichum fructus*, resembles the ordinary black rot under some conditions, when the formation of setose acervuli is prevented.

Leaves and twigs of seedlings grown from seeds of Grimes Golden apples, artificially inoculated, became infected by *Colletotrichum fructus;* setose acervuli were produced on such leaves and twigs.

Penetration by the fungus into the leaves seems to occur directly through the epidermis.

High atmospheric humidity is necessary for the formation of acervuli on fruit, and for the development of the disease on leaves.

DEPARTMENT OF BOTANY,
UNIVERSITY OF ILLINOIS,
URBANA, ILLINOIS.

PHYTOPATHOLOGICAL NOTE

Black Ear Rot of Corn.—Recently,[1] the junior author, while examining pure lines of corn, found that some of them were generally and severely affected with a black rot (Fig. 1). The affected ears were brought into the laboratory, where isolations were made from the blackened kernels after they were treated for 10 minutes with concentrated sulphuric acid. These isolations uniformly produced growth of a Helminthosporium, often in pure culture. So far as could be determined, the fungus is *H. turcicum* Pass., commonly found causing leaf blight of corn.

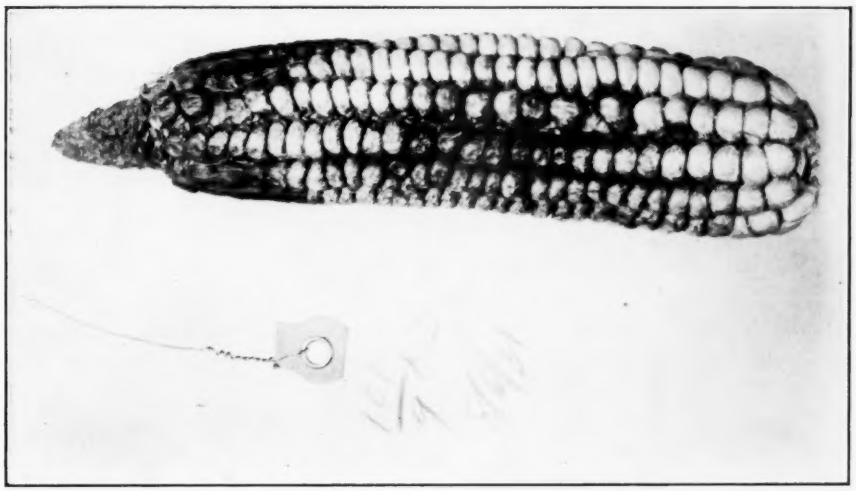


FIG. 1. Black ear rot of corn caused by *Helminthosporium turcicum* Pass.

The available literature shows no previous record of Helminthosporium causing ear rot of corn; hence it was thought that this note might be of interest to other plant pathologists. Since the disease has been observed in only 5 pure lines belonging to only 3 families of highly inbred corn (now in F_7), out of nearly 500 pure lines, belonging to 74 families, all of one variety (Neal's Paymaster), the subject may be of interest also to plant breeders.—C. D. SHERBAKOFF AND L. S. MAYER, University of Tennessee, Agricultural Experiment Station.

[1] August 6, 1931. The delay in publishing this note is due to the authors' hope of a further study of the subject—a hope that at present cannot be realized.

BOOK REVIEW

Wolf, Frederick A. *Tobacco Diseases and Decays.* 454 pp. 111 figures. Duke University Press, Durham, N. C. 1935. $5.00.

It is fitting that the first comprehensive publication on the diseases of tobacco should be written by a professor of botany of Duke University and published by the press of that University. The University is situated in the flue-cured tobacco district of North Carolina. The soil in this district is of low fertility, necessitating a heavy application of a well-balanced fertilizer each year in order to grow a crop of the proper quality. This has afforded the author an excellent opportunity to become acquainted with the mineral requirements of tobacco, as well as to observe the effect of excess elements on the crop. This is an excellent region for study of the numerous bacterial and fungus diseases to which tobacco is subject, especially the root diseases. The biological activities are apparently so low in this sandy soil that there is little or no inhibition of the soil-borne pathogens. The author has not neglected the opportunity to obtain first-hand information on the numerous diseases of tobacco occurring in that vicinity. His familiarity with foreign languages and his excellent mycological background have aided him in bringing together the foreign literature on tobacco diseases. The material is well evaluated and written in a clear style. The book may be considered an authoritative source of information on the present status of tobacco diseases.

The volume opens with a short discussion of the nature and kinds of plant diseases, based upon causes, followed by a classification and a short and very interesting history of tobacco. Then follows a discussion of seedbed practices in relation to control of diseases. Included is a discussion of the conspicuous non-pathogenic fungi that may be found in the plant bed.

A chapter on "Nutritional Diseases" follows. The inadequacy of the present methods of studying plant requirements is pointed out. The rôle of the essential elements in plant nutrition is discussed, where known, and also the effect of insufficient as well as excessive amounts of essential elements, and of several nonessential elements, on the tobacco plant.

Chapters follow on "Diseases Due to Unfavorable Water Relations" and "Disorders and Diseased Conditions of Tobacco That Are Little Known and Noninfectious." The latter chapter brings together many minor troubles, but fails to mention chlorosis of seedlings caused by cold, a condition quite common in plant beds north of the region in which the author resides, and one which, following partial recovery, is sometimes mistaken for mosaic. The discussion of frenching contains much new material originating in the laboratory of the author. Included is a histological study of frenched

leaves and considerable data on frenched and healthy plants. The author quite properly draws no conclusions as to the cause of frenching.

The chapter on virus diseases includes a comprehensive discussion of virus diseases of tobacco the world over. The discussion of tobacco mosaic is the most complete the writer has seen, and is well-balanced. It includes an excellent discussion of the epiphytology of mosaic, based largely on original research and the excellent work of Lehman. While recognition is given to the part that smoking and chewing tobacco play in initial plant-bed and field infection, undue stress appears to have been laid on manufactured tobacco as a source of mosaic, while no mention is made of cured tobacco taken directly from the barn. In the Burley and dark-tobacco areas of Kentucky, Tennessee, Virginia, and neighboring States, barn-cured tobacco is commonly used for pipe smoking and chewing by tobacco growers, and constitutes a much more extensive source of mosaic than manufactured tobacco. There is good evidence that manufactured tobacco may be substituted for barn-cured tobacco with marked reduction in the incidence of the disease. The discussion on mosaic is sufficiently complete and so clearly stated that an intelligent person, after studying it, should have little difficulty in determining what has occurred in any severe outbreak of mosaic and in pointing out means of future prevention.

In the discussion of the tobacco-mosaic virus, the author seems to have fallen into the error of accepting the host range established by Elmer for viruses of Solanaceae as that of the tobacco-mosaic virus. Elmer undoubtedly worked, in part at least, with the group of cucumber-mosaic viruses. The author might better have confined host range of tobacco-mosaic virus to that given by Grant, whose paper is not listed in the references on tobacco mosaic, but is listed in the more complete bibliography at the end of the book. A mistake was made in separating the discussion of "yellow mosaic" from that of tobacco mosaic, as yellow mosaic appears to be caused by one or another of several strains of the tobacco-mosaic virus carried in solanaceous weeds. The author properly separated cucumber-mosaic viruses from the tobacco mosaic group rather than include some of them, as was done by[1] K. M. Smith in his "Recent Advances in Plant Viruses," (p. 358). A comprehensive review of the literature on other virus diseases of tobacco is included. The suggestion that kromnek and corcova are identical diseases seems logical. The delphinium virus might better have been discussed with the cucumber-mosaic viruses, a group of which commonly affect tobacco in the field. Coarse etch should not have been included with the etch viruses, as it has little in common with them, except the name.

[1] Smith, K. M. Recent advances in plant viruses. 423 pp. J. & A. Churchill, London. 1933.

The "Bacterial Diseases" are grouped in one chapter. The discussions are not merely a compilation of published material, for the author is very familiar with several of the diseases discussed as well as the pathogens concerned. The author does not agree with Stapp that *Bact. tabacum, Bact. angulatum* and *Bact. mellcum* are identical. Certainly, anyone who has worked with the leaf spots must recognize at least two distinct diseases, even though the pathogens are shown to be closely related. While the author is usually very cautious in his statements where controversial matter is concerned, he states that "observations, generally, are in accord in showing that wildfire invariably begins in the seed bed and is introduced into the field at time of transplanting." The bacterial leaf-spot diseases found in other countries are discussed, and an evaluation made of the evidence for the existence of distinct diseases.

The "Fungus Diseases" are considered in a single chapter. The discussions are very comprehensive. In view of the fact that the author has personally worked with nearly all the important fungus diseases considered, the discussions may be accepted as representing the latest and most authoritative information available. It might have been better if he stated that the organism responsible for the black root-rot disease of tobacco is commonly regarded as *Thielaviopsis basicola* rather than *Thielavia basicola,* as the former name is now commonly accepted. The discussion of downy mildew would have been improved had the full-page illustration used in The Bulletin (North Carolina Department of Agriculture, 1934) been used rather than or in addition to the figures after Spegazzini. The statement that White Burley tobacco, which is resistant to black root rot, is reported to be resistant to fusarium wilt is misleading.

A short chapter is devoted to nematodes, and a chapter to parasitic seed plants. *Orobanche ramosa* is the common broom rape attacking tobacco in Kentucky, and not *Orobanche ludoviciana,* as the author states.

The final chapter is devoted to "Decays of Tobacco During Curing, During Fermentation and Storage, and After Manufacture." There is a 50-page "Bibliography of Tobacco Diseases and Decays." This includes the list of references that follow the discussion of each individual topic.

The book is well written, well illustrated, and is printed on good paper. It is exceptionally free from errors, although a few appear. For example, Nolla, Guggenheim, and Roque, rather than Nolla and Roque, are credited in three places for the report on a mosaic-resistant tobacco. The book should be in the libraries of county agents in tobacco-growing areas, of field agents of cooperative and commercial tobacco organizations, of more intelligent tobacco growers, of high-school teachers in agriculture in tobacco-growing areas, and will be indispensable to research workers on tobacco diseases and to teachers of general Plant Pathology.—W. D. VALLEAU, Kentucky Agricultural Experiment Station, Lexington, Ky.